Mediated labour migration in the Myanmar-Thailand corridor and precarious outcomes: a mixed methods social network analysis and agent-based model

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Statement of Originality

I, Alys Mary McAlpine, confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in this thesis.

Abstract

Background: Global estimates indicate that 25 million people are in situations of 'modern slavery' in the form of forced labour or human trafficking, many of whom are migrant workers in low-wage sectors. Recent dialogue has linked 'unfair recruitment' with exploitative work outcomes. However, the definitional boundaries of recruiters and recruitment are still opaque and highly context-dependent. Many recruitment initiatives narrowly address *legal* recruitment and fail to address the circumstances of migrants navigating irregular migration corridors, such as between Myanmar and Thailand, which is the geographical focus of this thesis.

This thesis aims to explore how Myanmar migrants make decisions, plan, and navigate migration and the role of mixed social and intermediary networks. Additionally, this thesis describes a novel application of complex systems methods to explore and describe the complex causality of precarity or 'hyper-precarity' outcomes among migrants.

Methods: This thesis relied on three methodological components, including: 1) a systematic review; 2) mixed methods social network analysis of primary data collected in Thailand; and 3) development of an agent-based model using the primary data from Myanmar migrants. The systematic review synthesised study findings on the use of agent-based modelling in migration and modern slavery research. The mixed methods social network analysis study identified the range of actors, networks, and corresponding pathways in the Myanmar-Thailand corridor. The fieldwork included conducting interviews with 100 Myanmar migrants across three sites in Thailand (Mae Sot, Phang Nga, and Mahachai) using a custom-designed data collection tool to capture egocentric network maps and migration narratives. Finally, the structured social network data and unstructured data from semi-structured interviews with migrants were used to build an agent-based model and produce simulations to observe the emergence in migrant network composition, migration pathways, and migrant precarity outcomes.

Results: A broad range of social and intermediary actors influence and facilitate labour migration pathways between Myanmar and Thailand. Myanmar labour migrants experience hyper-precarities in the various pathways arranged by intermediary actors, but migration that is coordinated by family members, which generally involves irregular pathways, was the least precarious in terms of livelihood, immigration, work, and social factors. Findings also show that migrant precarity is not static throughout the journey or even once migrants are at their destination, because there remain numerous decisions and events that can increase or reduce precarity, such as changes in workplace or documentation.

The methodological findings indicate that complex systems' approaches, and specifically agent-based modelling, have not been used to explore low-wage labour migrants' decision-making or migration pathways – particularly the role of intermediaries. Further, migration ABMs more generally have been limited in their empirical-embeddedness and have rarely drawn on participatory or qualitative methods to inform the model design. The complex system, mixed methods study design implemented in this thesis shows the feasibility and appropriateness of mixed methods social network analysis to inform *and* validate migration ABMs.

Conclusion: This thesis fills a gap in our understanding of mediated migration in the Myanmar-Thailand corridor and how mediated pathways shape migrants' varied experiences and about the potential roles of intermediaries in precarity-related outcomes. The empirical findings suggest that there are a variety of intermediaries who play diverse roles, which do not conform to many of the stereotypes assumed in safe migration dialogue or interventions. Findings indicate that current assumptions do not reflect the reality of the roles of intermediaries or associated risks for migration outcomes. The empirical contributions of this work challenge current 'safe migration' intervention assumptions, especially the simplistic dichotomy of regular/legal versus irregular/illegal migration. Further, the methodological

advancements offer a promising way to identify and test intervention assumptions and simulate potential intervention outcome pathways. Ultimately, this work argues that to make migration *safer*, not just more orderly, we first need to abandon erroneous dichotomies about risk. Once these assumptions are discarded, then we can generate and apply evidence about the complex causal mechanisms that determine labour migration outcomes using data that reflects migrants' choices, experiences and contextual realities.

Table of Contents

List of Figures

List of Tables

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Covid-19 Impact Statement

The Covid-19 pandemic prohibited me from completing some of the activities that were part of my PhD plan .

1. One of my thesis papers was accepted to the *Migration Methodologies Workshop* hosted by the Asia Research Institute at the National University of Singapore. This workshop would have provided me with peer feedback and the paper was intended to be published in a special issue journal. Unfortunately, the March 2020 workshop was postponed to November 2020 and eventually cancelled indefinitely. This was a lost opportunity for peer-feedback and delayed the publication of this paper, which was first drafted in April 2020. However, this paper has now been submitted elsewhere for peer-review and publication.
2. I was accepted to The Alan Turing Institute's (ATI) *PhD Enrichment Programme*, which consisted of an in-person placement at their institute from October 2020 - March 2021. My hope was to use this placement to collaborate with other multi-agent system modellers to verify and validate the agent-based model (ABM) that is part of this thesis. The usual in-person programme was replaced with an online *Engage@Turing* programme that had more emphasis on PhD cohort community building. It did not allow for the same engagement with more senior ATI fellows for support in the areas of model evaluation I was hoping to receive. However, I have confirmed plans for interdisciplinary knowledge exchange with ATI fellows as part of an upcoming ESRC-funded methods innovation grant , which will include work on validation ABMs.
3. As part of my ABM validation plans, I had intended to facilitate participatory validation workshops in-person with key stakeholder groups (migrant workers, NGOs, policy makers, etc.). I concluded this work would be challenging to pilot remotely and more successful in-person, so I have shifted these plans to take place as part of my post-doc work that will build on this thesis work.

Abbreviations and Acronyms

3-D	Dirty, Dangerous, and Difficult (or sometimes 'demeaning')
ABM	Agent-Based Modelling
ASEAN	Association of Southeast Asian Nations
CF	Conceptual Framework
CHIME	*Capitalising Human Mobility for Poverty Alleviation and Inclusive Development for Myanmar* (CHIME) study
CSO	Central Statistical Organization
ESRC	Economic and Social Research Council
Ego-Net	Egocentric Network
EPP	Employer Pays Principle
FED	Foundation for Educational Development
GDP	Gross Domestic Product
GSI	Global Slavery Index
IBM	Individual-Based Model
IHPP	International Health Policy Program
ILO	International labour organization
IOM	International Organisation of Migration
LMIC	Low- or middle-income countries
LSHTM	London School of Hygiene and Tropical medicine
MAP	Migrant Assistance Programme
MAS	Multi-Agent System
MDG	Millennium Development Goals
MLCS	Myanmar Living Conditions Survey
MMK	Myanmar Kyat
MMSNA	Mixed methods Social Network Analysis
MOU	Memorandum of Understanding
PID	Participant identification
SA	Sensitivity Analysis
SDG	Sustainable Development Goal
SNA	Social Network Analysis
THB	Thai Baht
UN	United Nations
UNDP	United Nations Development Programme
UNDESA	United Nations Department of Economic and Social Affairs
USD	United States Dollar

Thesis overview. This thesis is written in 'Research Paper' style and includes four papers. The papers are preceded by the following chapters: a discussion of the linkages between international low-wage labour migration and forms of modern slavery (Chapter 1); a presentation of the theory and original conceptual framework that guided this work (Chapter 2); and a description of the integrated mixed methods study design for this thesis (Chapter 3).

Chapter 1 first describes the global phenomenon of labour migration and exploitation, followed by an overview of the international response to unfair recruitment practices. Chapter 1 then focuses more specifically on labour migration from Myanmar to Thailand, which is the geographic focus of this thesis. This discussion includes background information on Myanmar-Thailand labour migration and exploitation trends, bi-lateral immigration policy, and migration mediation (e.g., intermediaries and social networks). Chapter 1 concludes with the study rationale and the thesis aim and objectives.

Chapter 2 details the theory that informed the conceptual framework and methodological choices for this thesis. This chapter also presents the conceptual framework – the complex low-wage labour migration system framework – which guided the research design and data collection.

Chapter 3 presents my epistemological position related to this research and a detailed explanation of the integrated mixed methods framework. This chapter provides the rationale for the study design, ethical considerations, sampling methods, fieldwork, and data collection, as well as my reflexivity statement.

Chapter 4 includes the four research papers:

> **Paper 1** is a systematic review that synthesises the use of agent-based modelling (ABM) in migration and modern-slavery research.

Paper 2 is a methods paper that describes the design of a mixed methods social network analysis (MMSNA) study and the use of novel visual network tools for data collection and analysis.

Paper 3 is an analysis paper that presents the MMSNA study findings on Myanmar migrants' networks and pathways to Thailand (using the tools described in Paper 2).

Paper 4 is an analysis paper that presents an empirically-based ABM of labour migration networks and pathways from Myanmar to Thailand (guided by Papers 1 and informed by Paper 3).

Chapter 5 summarises the thesis findings and discusses the implications of the findings for migrants, interventions (i.e., programs and policy), and future research. This chapter addresses the limitations and contributions of this work and concludes the thesis while setting the agenda for the next steps for this research.

Finally, the **Appendices** contain a breadth of supplementary materials that are sign-posted throughout this thesis, including, for example: documentation of how the conceptual framework developed (Ch. 2); the systematic review protocol (Paper 1); visuals of the design process for the data collection instrument and MMSNA interface (Paper 2); anonymised case study examples of the interview data (Paper 3); ABM sub-model schematics and rules (Paper 4); and materials from recent presentations of the preliminary findings to stakeholder groups (Chapter 5).

Chapter 1. Background

International migrants frequently fill low-wage jobs in sectors of work notoriously described as dirty, dangerous, and difficult ('3-D jobs'), which are generally undesirable to native populations (1–3). Migrants employed in 3-D jobs are often exposed to occupational hazards, exploitative employment practices, and various forms of modern slavery at disproportionately high rates compared to the native working population (1, 2, 4–6). Global estimates indicate that 25 million people, many of them migrant workers, are victims of forced labour comprising an international human rights and public health concern of global proportions (4).

Over the past three decades, migration and health researchers have established growing evidence of the prevalence and severity of labour exploitation and associated adverse health outcomes among migrant populations (6–8). To tackle this global public health problem, international and inter-agency stakeholder groups, such as the United Nations (UN) and the World Health Organization (WHO), are establishing policies that aim to promote the health, safety, and wellbeing of migrants in various types of work (9, 10). In response to emerging evidence of the links between unfair labour recruitment practices and labour exploitation, the International Labour Organization (ILO) is leading a global initiative to establish a model of 'fair recruitment' to guide intervention and policy frameworks (11). At the same time, public health experts studying labour migration and human trafficking argue that there remains a scarcity of intervention research to move beyond measuring the prevalence of the problem (7, 12). For example, research is limited on causal pathways linking migration and labour exploitation and there are few evaluations of programme or policy interventions. Establishing evidence to inform and evaluate interventions is particularly difficult because, like many public health challenges, labour exploitation operates within complex social and political systems that require multi-level interventions (13). Population health intervention

specialists are advocating for increased uptake of complex systems theories and approaches to guide intervention development and evaluation (13).

This thesis offers both empirical insights on complex causality of labour migration outcomes to inform intervention designs and provides a methodological proof of concept to advance the use of complex system methodologies in migration- and health-related research.

Section 1.1 briefly describes the research partnership and preliminary 2015 scoping reviews that informed the thesis proposal. **Section 1.2** describes current trends in international low-wage labour migration, occupational health risks for migrant workers, exploitation and modern slavery, and the linkages between intermediaries and modern slavery. **Section 1.3** concludes this chapter with a description of low-wage migration and labour exploitation trends in the Myanmar-Thailand migration corridor, which is the geographic focus of this thesis.

1.1 Research partnership and 2015 scoping reviews

This thesis builds on previous research conducted by our team of migration and health researchers at the London School of Hygiene and Tropical Medicine (LSHTM), in partnership with the Freedom Fund, a leader in the global movement to end modern slavery.

In 2015, I and my current supervisors at LSHTM, Professor Cathy Zimmerman and Dr Ligia Kiss, were commissioned by the Freedom Fund to author a series of literature reviews to inform their ongoing community-based safe migration initiatives. The aim of this research was to take stock of the evidence for safe migration programming, which included: a review of evaluations of safe migration interventions; a thematic synthesis of the evidence on risk and protective factors for labour migration outcomes; and a scoping review of relevant social and behavioural theories that might guide future intervention research and development. In brief, these reviews concluded that there was limited evidence on what interventions successfully promoted safe migration or prevented modern slavery, if any, and opaque or insufficient conceptualisations of 'risk' to inform intervention design and policy (14). Moreover, there was a concerning tendency for stakeholder organisations to implement poorly evidenced programmatic assumptions and sometimes present them as de facto theories of change – or not acknowledge a theory of change at all. Most of the intervention documentation and evaluations we reviewed did not explicitly address specific, contextually relevant, or evidence-based causal mechanisms.

When risk was addressed in the literature, explanations were often vague or simplistic and rarely acknowledged the interactions or dynamics of risk across different migration stages, geographic contexts, or intersectional identity groups. Furthermore, the risks described were usually singular individual factors (e.g., gender, socioeconomic status) or structural problems (e.g., sector wide low-wages, dangerous work environments).

Most of these risks could not be addressed with community-based interventions nor were they capturing the emergent system of exploitation that results from the multi-level and interacting exposures that migrant workers are likely to encounter. Addressing the complex causality of migrant labour exploitation requires examining, for instance, the compounding effects of under-resourced migrants, discrimination at destination, complicated immigration procedures, expensive documentation, formal and informal systems of labour mediation, and unequal employer-employee power relations. Without an exploration of context-specific causal mechanisms there was extremely little analysis of how risks might appear or operate in different situations for different individuals (14). Protective factors were discussed even less. Frequently, 'safe' and 'unsafe' migration were conceptualised retrospectively starting with the outcomes (e.g., if an individual was trafficked then their migration was unsafe) instead of focusing on the causal mechanisms at the nexus of migration and low-wage labour that results in the high prevalence of modern slavery. For example, there were rarely discussions of the decision-making, planning, or transactions that take place throughout labour migrants' transit to destination and into low-wage work.

The evidence gaps on risk that were highlighted by that 2015 scoping review were starkly juxtaposed to the anti-trafficking field's increasing investments into 'safe migration' interventions, often in the form of awareness campaigns (e.g., community awareness raising or targeted pre-migration trainings) (14). But the question we had at the outset of that review was left unanswered: *What are the risks and protective factors for different labour migration outcomes, for whom, and in which contexts?* Additionally, a further question persisted: *How do risks interact dynamically over time and geographies?* Since these fundamental migration-related questions remain unanswered by the scientific community, the practitioner community requires answers to important community-based programming questions,

such as: *What information on 'risk' is being circulated to migrant communities? What specific advice are we 'prescribing' to prospective migrants as measures or suggested behaviours to keep them safe?*

In 2015, we presented these scoping reviews at a two-day stakeholder workshop. The group unanimously confirmed there was a stark absence of evidence-based theories of change informing intervention development to prevent labour exploitation and that this needed to be a priority for the field of anti-trafficking and modern slavery prevention. The group acknowledged that establishing explicit causal roadmaps was the first step to ensuring scarce resources are invested into the most promising interventions. In other words, to improve programme effectiveness, program designers had to reposition the causal evidence horse in front of the intervention carriage. This thesis argues that we must adopt complex systems theory and methods to explore context-specific causal mechanisms as a departure from conventional methods that are only able to capture correlations of individual level risk factors. Context-specific understanding of causal mechanisms may prevent repeatedly misguided and untested one-size-fits-all approaches to interventions that narrowly address mainly or solely individual risks.

Based on this previous work, we applied for and received joint funding from the Economic and Social Research Council (ESRC) for a collaborative doctoral studentship. Our 2015 scoping reviews informed the research questions addressed by this thesis, questions concerned with *how* individuals migrate, *who* mediates these migration processes, and *which*, if any, of these migration pathway characteristics might include causal 'risk' or protective mechanisms.

The aim of this thesis is to describe the complex system of low-wage labour migration mediation (e.g., recruitment, smuggling, social networks) in the Myanmar-Thailand corridor and offer preliminary explanations of possible causal mechanisms leading to labour migration outcomes.

1.2 International low-wage labour migration, health, and exploitation

1.2.1 International low-wage labour migration

According to the International labour organization (ILO), there are approximately 258 million international migrants worldwide, and most are employed in some form of work (64%) (15). Labour migration, as defined by the International organisation for migration (IOM), is "the movement of people, either cross-border or within their country of residence, for the purpose of employment" (16). The terms 'labour migrant', 'economic migrant' and 'migrant worker' are often used interchangeably to describe an individual who participates in labour migration in any given geographic migration corridor. An international 'migration corridor' is a term used to describe a dyadic pair (i.e., origin and destination) of countries or regions with established and highly frequented migration routes, such as migration from Mexico to the USA, Ethiopia to the Gulf States, or Myanmar to Thailand. Labour migrants are employed in almost all sectors, but their roles are often at the extreme ends of the labour market, in either highly remunerated senior or specialist posts or, more often, jobs at the lowest paid point of entry into the labour market (i.e., 'low-wage migrant workers').

It is assumed that current labour migration prevalence figures are underestimates because of the operational challenges to collecting real-time data on migrant flows (e.g., inconsistent definitions, failures in routine monitoring, obstacles to responsible data sharing) (17, 18). These challenges are intensified in attempts to capture the magnitude of irregular migration flows (19, 20). The IOM defines 'irregular migration' as the "movement of persons that takes place outside the laws, regulations, or international agreements governing the entry into or exit from the State of origin, transit or destination" (16). In migration corridors with highly porous borders, many if not most labour migrants cross the border outside of formal immigration checkpoints and thus are not counted in routine monitoring totals. In many contexts rates of 'apprehension' of irregular migrants is the only indicator

available to estimate the magnitude and dynamics of this phenomenon. Researchers and subject experts argue that this method significantly underestimates the true total, does not adequately distinguish between *types* of irregularity, and cannot offer accurate evidence on changes in trends of irregular migrants over time. (19, 20)

Most migrant workers, especially those with irregular status, are employed in low-wage and precarious jobs. Low cost labour has emerged as a common and essential feature of many industries in our global economy, especially in high export economies like Thailand that aim to achieve high gross margins on goods (3). Modern trends in mass consumerism, such as fast fashion or over-consumption of seafood, rely on a race to the bottom for cheap labour (21, 22). Of course, 'cheap' does not mean the overall costs of production dissipate, but instead that the cost-saving achieved by suppliers, producers, and consumers is often at the financial and personal expense of workers in the form of low-wages, long hours, no healthcare, distance from home, and precarious status.

The construct of 'cheap' is often used as a relative descriptor. King and Ruenda conceptualise "cheap labour in non-standard employment" (e.g., temporary or precarious work) as labour completed for low-wages, without protections, and with minimal benefits, if any (23). These non-standard low-wage jobs are often filled by those with limited or constrained alternative livelihood options, opportunities for social upward mobility, or agency in the labour market (24, 25). The demographics of low-wage workforces have evolved over time and differ across contexts, but usually share a common pre-existing characteristic of social disadvantage (24, 26). For example, at one point in time, low-wage workers in advanced industrialised cities were predominantly women, teenagers, and children, including large groups of domestic migrants from rural areas, but shifts in household structures, gendered dynamics of work, norms around education, and teenagers' engagement with work training allowed women and teenagers to enter

higher wage work and children to enrol and remain in school (27, 28). This labour force shift left a gap in the labour market that few nationals wanted to fill and, in many cases since, has been filled by international migrants unable to secure sufficient employment at home.

Immigrants are an essential source of labour for many advanced industrial countries in our globalised economy (15). However, labour migrants in 3-D or informal work are often marginalised and neglected by the destination countries where they are employed, as they do not have access to certain protections or grievance mechanisms. Low-wage workers frequently experience occupational hazards and abuse in their employment, in part, because of pervasive intersectional discrimination against them as both immigrants and low-wage workers. Frequently 'low-wage' migrant workers are stereotyped as 'low-skill' workers, which can be used as further justification for discriminatory wages even though the principals of hazard-related wage premiums introduced in many developed contexts should mean that this workforce should be compensated with higher pay for their exposure to occupational hazards and the job-related physical toll (29).

The remainder of this thesis will focus on trends and experiences of international and low-wage labour migrants, since the empirical focus is cross-border migration between Myanmar and Thailand into 3-D sector work.

1.2.2 Occupational health risks for migrant workers

The objective of the World Health Organization (WHO) is to attain the highest possible level of health for all people and within this mandate, they aim to promote the improvement of "economic or working conditions and other aspects of environmental hygiene" (30). At present, low-wage international migrant workers are more likely to work in occupationally hazardous employment than their native counterparts (1, 2, 6, 31).

In 2017, Hargreaves and colleagues[1] conducted a systematic review and meta-analysis of studies that reported the occupational health outcomes of international migrant workers with the aim of summarising the global prevalence of this population's occupational morbidity (6). The meta-analysis concluded that 47% (95% CI 29–64; I^2=99·70%) of international migrant workers reported at least one occupational morbidity (e.g., musculoskeletal disorders, gastrointestinal issues, respiratory conditions) and 22% (7–37; I^2=99·35%) reported at least one injury or accident (e.g., falls from heights, lacerations, fractures) (6). The review confirmed that migrants are often employed in more occupationally hazardous sectors than non-migrants (1, 2, 8, 32). Furthermore, these findings highlight mounting evidence suggesting that, in some contexts, migrants experience higher rates of occupational morbidity and mortality than their native co-workers employed in the same jobs (6, 31, 33). For example, Dong and Platner found that, between 1992-2000, Hispanic migrant construction workers in the United States were nearly twice as likely to experience a fatal occupational injury than their non-Hispanic counterparts (34). The recent UCL-Lancet Commission on Migration and Health[2] gave specific attention to the compounding risk exposures that cause disproportionate prevalence of adverse occupational health outcomes among migrant populations, including risks associated with their social contexts and living conditions at destination (8).

It is likely that one important determinant of these disproportionate workplace risks is the absence of sufficient occupational safety and health (OSH) training or personal protective equipment (PPE) for migrant workers

[1] During her doctoral studies, Alys McAlpine was a co-author of this systematic review on occupational health outcomes among international migrant workers. Additional information on this review and its findings can be found in Appendix 1.

[2] During her doctoral studies, Alys McAlpine was a contributing author to the UCL-Lancet Commission on Migration and Health. McAlpine co-authored the sections on labour migration with Professor Cathy Zimmerman and conducted the thematic literature review to produce the migrant worker occupational health table in Appendix 1.

(6, 8, 33). Without these protective mechanisms in place, many migrants experience chronic exposure to more severe direct hazards (e.g., harsh chemicals, dangerous machinery, lifting heavy loads) than non-migrants. The health risks caused by these direct exposures can be exacerbated by language barriers or discrimination, which can disadvantage many migrant workers (35). Moreover, international migrant workers face a myriad of barriers to seeking health-care, such as, not qualifying for medical subsidies or financing schemes, fear of deportation, inability to take time off work to access services, or xenophobic discrimination at point of services (36, 37). While some progress is being made toward migrant-inclusive healthcare made in some regions, there are still many logistical, financial, and political barriers to ensuring undocumented workers have rights to health services at destination and they can access those services (38). These compounding barriers to OSH protections and health care often amplify the health consequences of occupational morbidity for migrant workers in 3-D sectors.

The migrant labour force is indispensable to many sectors, but often individuals within this workforce are treated as disposable and replaceable low cost, 'low skill' labour, which contributes to the pervasive disregard for migrant workers' health and wellbeing. The UN Sustainable Development Goal[3] 8 (SDG 8) calls on governments to address barriers to decent work and economic growth by protecting and promoting the rights and safety of all workers, *including* migrant workers (39). However, an ILO report assessed the progress toward achieving SDG 8 and concluded that progress has slowed, and worsening workplace inequalities make achieving SDG 8 by 2030 unrealistic, even with significant increased investments, as requested by many inter-agency stakeholders (40).

[3] In 2015, the UN adopted the 2030 Agenda for Sustainable Development, guided by 17 'Sustainable Development Goals' which recognise that, "ending poverty and other deprivations must go hand-in-hand with strategies that improve health and education, reduce inequality, and spur economic growth" (9).

1.2.3 Exploitation and 'modern slavery'

In addition to the multiple occupational health risks that international migrants face in hazardous sectors, they also experience complex and interacting exposures to a range of exploitative practices (7, 41). Zimmerman and Kiss conceptualise these exploitation-related risks as a combination of abuse, occupational hazards, and poor living conditions (Figure 1) (7). In some cases, migrants experience severe forms of exploitation that amount to human trafficking or 'modern slavery'.

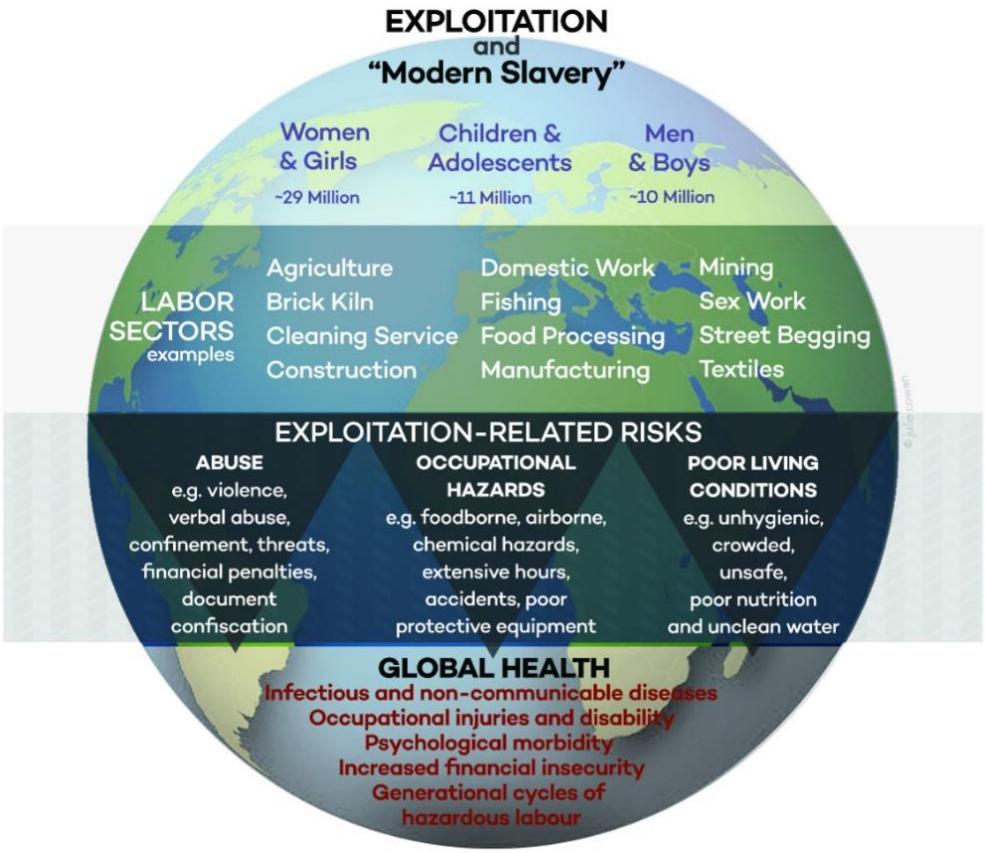

Figure 1. Exploitation, risks, and global health, Zimmerman & Kiss 2017 (7)

Brief note on 'modern slavery' terminology and measurement

The term 'modern slavery' is not legally defined, but it is increasingly used as an umbrella term to describe extreme labour exploitation, alternately referred to as forced labour and human trafficking. While the rhetorical

debate on exploitation terminology has been described as “vitriolic” and perhaps unnecessarily semantical at times (42), there are of course legal, political, and advocacy implications to how these terms are used. International law and human rights scholar, Janie Chaung, argues that the problematic conflation of labour exploitation terminology, or what she calls the “exploitation creep”, has led to a “rigor-free zone” that presents serious challenges for defining the legal parameters of these crimes (43, 44). Adequately untangling the history and current application of these terms is beyond the scope this thesis so instead, for succinctness, this thesis will use the terms ‘modern slavery’ or ‘labour exploitation’ to refer to the broad gamut of trafficking and slavery-like experiences, unless specified otherwise.

Furthermore, this thesis adopts the perspective of scholars such as Skrivankova, who posit that regardless of what terminology we use, the “reality of forced labour is not a static one, but a continuum of experiences and situations . . . a continuum should therefore be used to describe the complexity of the exploitative environment and concrete individual situations of workers” (41). The ‘outcome continuum’ can be, and in many cases has been, applied to the conceptualisation of most labour migration outcomes (e.g., occupational health, labour exploitation, worker compensation, migrant worker precarity) (Figure 2). However, to date, most of the methodological advancements in measuring forms of modern slavery have focused on developing global indicators to measure the prevalence of outcomes framed as dichotomous, for example, fair versus unfair recruitment, forced labour versus decent work. Research on the magnitude and nature of modern slavery rarely addresses these exploitation ‘continuums’ – *what types, how exploitative, for whom, and to what harm?* As Julia O’Connell Davidson explains, “to ring fence ‘trafficking’ would therefore require us to make a judgement about what constitutes appropriate and inappropriate exploitation, and what counts as force, in a huge number of vastly different contexts. Throw in the fact that social norms

pertaining to these markets, institutions and practices differ from country to country, and the task looks even more hopeless" (45).

This thesis applies a continuum perspective to labour migration outcomes, as indicated in the examples in Figure 2. Adopting a 'continuum perspective' means understanding that outcomes can occur along a spectrum from better to worse. This figure illustrates a selection of labour migration outcomes (e.g., recruitment, precarity, worker compensation) that can be viewed along a continuum, some relatively favourable and some unfavourable. The green box/text depicts the favourable ends of the continuum, and the red box/text depicts the unfavourable ends, which are also defined in the figure box. For example, the recruitment continuum includes a range of outcomes spanning from ILO's definition of 'unfree' recruitment to ILO's definition of 'fair' recruitment. Likewise, the precarity continuum is informed by Hannah Lewis's work conceptualising 'hyper-precarity', which illuminates the many immigration, labour, and social indicators that determine an individual's experience of precarity within a larger precarious system (26). The figure also includes a worker compensation continuum, which is informed by Benjamin Harkin's commentary on the varied and multi-dimensional experience of 'wage theft' (e.g., unfair wages, deductions, discriminatory pay, etc.) (46). These outcomes, and the additional outcomes in the figure, can each emerge along different ranges and with varying dynamics depending on the context (e.g., geography and sector). The figure provides one example using wage theft to demonstrate how these continuums might be shaped by the specific context. Finally, this figure poses the continuum questions that are rarely addressed in empirical work on labour migration outcomes: *How do migrant workers perceive their own labour migration outcomes? And what do they define as 'successful' migration?* This figure builds on recent empirical and conceptual work that attempts to depart from simple, dichotomous definitions of labour migration, exploitation, and health outcomes.

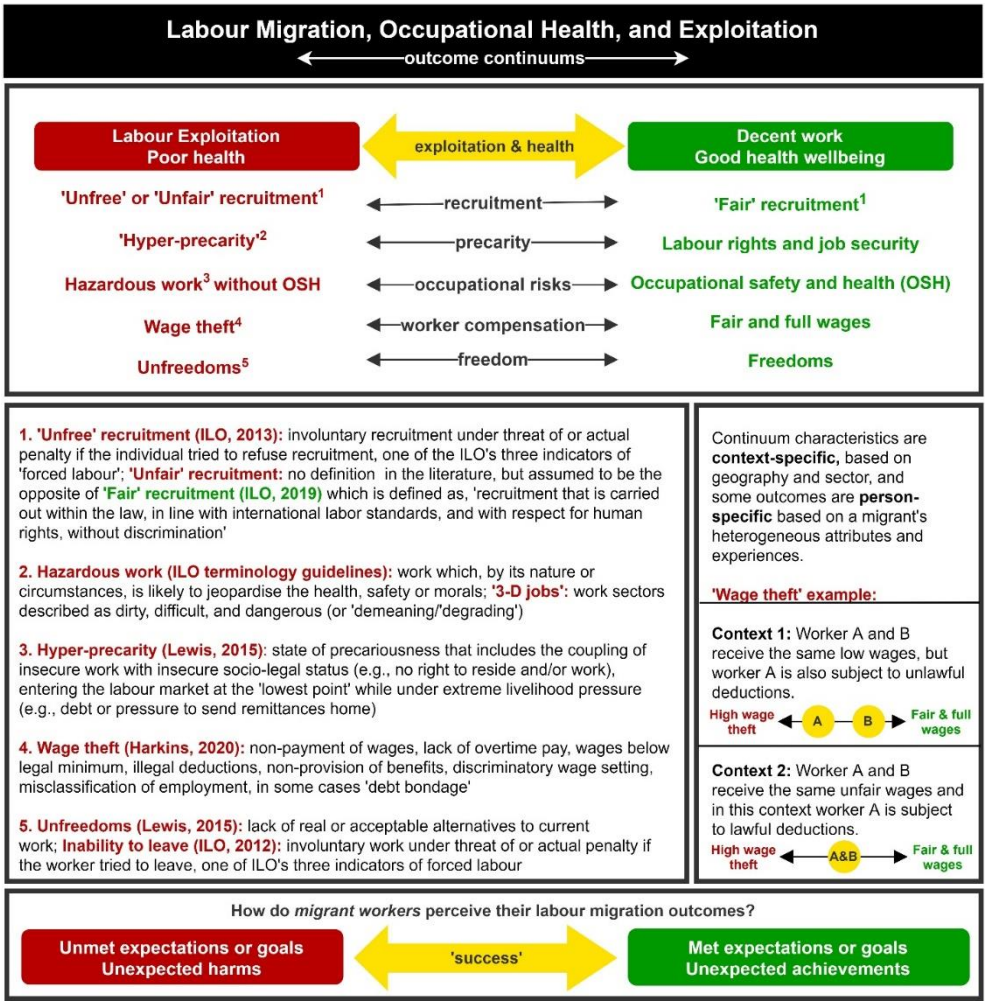

Figure 2. Labour migration, occupational health, and exploitation – outcome continuums

Prevalence and nature of migrant exploitation and modern slavery

There is not currently a reliable estimate of the prevalence of international migrants in situations of modern slavery, but the ILO estimates that approximately 25 million people are in situations of forced labour and that 23% are exploited outside of their country of birth (4, 47). These global estimates are generally accepted to be underestimations given the sensitive and criminal nature of this phenomenon, as well as the many challenges to collecting reliable and generalizable data from this hard-to-reach population (48, 49).

All forms of modern slavery are associated with severe and life-threatening mental, physical, and financial harm (50–55). For example, the largest survey to date on the health outcomes of trafficking survivors, led by Prof Zimmerman and Dr Kiss (hereafter the 'STEAM study'), found that one-third of male trafficking survivor-respondents in post-trafficking services in the Greater Mekong region had experienced severe violence and sustained injuries while trafficked in the commercial fishing or manufacturing sectors (56). Similar research conducted by the ILO concurred with these findings in the fishing sector (57).

More frequent types of labour exploitation include the widespread practice of 'wage theft' in the forms of unfair wages, wage deductions, or missed payments (46). In the same landmark survey in the Greater Mekong region, Kiss and colleagues found that 75% of men and 80% of women reported being "cheated of their wages" and that exposure to this form of exploitation was significantly associated with anxiety and post-traumatic stress disorder (PTSD) (58). Moreover, many irregular migrants' experiences of exploitation are exacerbated by their limited access to grievance resolution mechanisms due to their undocumented or precarious status (38).

Because the abuses and exploitative practices in low-wage or no-wage work create serious health risks, and, in the most severe cases, cause life-threatening injuries, disability or death, this thesis adopts a public health perspective. Informed by the work of Zimmerman and Kiss, this thesis undertakes a public-health approach—or 'prevention lens' – to explore the multiple interacting determinants that might put international migrants at risk of exploitation, at the centre of which is their labour migration process (7).

1.2.4 Links between intermediaries and 'modern slavery'

Labour migrants rarely migrate without assistance from intermediary actors (59–61), therefore, understanding the role of intermediaries is essential to understanding labour migration processes, decisions, and outcomes (59,

62). Dr Katharine Jones, a subject expert on migration mediation, conducted an extensive literature review to address what she refers to as a "dizzying array of terminology" used to describe intermediaries (61). Drawing on definitions in the empirical and theoretical literature, she suggests the following working definition:

> "An intermediary is an actor or institution that fosters, facilitates or sustains human mobility. The mediating or brokerage process is relational and often involves interactions of multiple actors operating within complex local-global, socio-economic, cultural and political environments. The practices of intermediaries often blur the boundaries between commercial and non-commercial, private and public, state and market, formal and informal, legal and illegal due to the complex nature and conditions in which this "middle-space" exists." (61, p. 15)

In many migration corridors, the current discourse on intermediaries highlights the nuanced, complex, and, at times, conflicting characterisations of these different "middle-space" actors – "credible" or "colluding" *brokers* (63), "good" or "bad" *smugglers* (64), unscrupulous *recruiters* (65), well-connected knowledgeable *mediators* (62), life-lines in moments of crisis (66), and so on. Most of these portrayals, once unpicked, negate simple dichotomies. For example, Achillis' ethnographic work on human smuggling in the Balkan migration corridor poses a provocative profile of the "good" smuggler and goes on to conclude that many of the migration stories he heard "problematize simplistic categorizations of smugglers" and challenge the dominant, overly narrow stereotypes of profit-driven criminals (64). Awumbila and Deshingkar's research on labour migration brokerage in Ghana reports on the "complex and contradictory" role a broker may play in facilitating entry into exploitative labour, and conversely providing essential and beneficial services to workers before and after arrival (63).

Depending on the geography, context, and migration drivers (e.g., economically motivated, conflict induced, mixed) the relevant intermediaries may differ. For example, smugglers were the prominent

intermediaries in the Mediterranean migration 'crisis', given the high demand for immediate transit outside of formal channels (67). Whereas, in recent years, much of the international debate on potentially harmful or exploitative labour migration mediation has focused overwhelmingly on the role of recruiters (14, 61). This attention is, in part, because emerging evidence in some contexts has linked abusive recruitment practices (e.g., exorbitant fees, contract swapping) to labour exploitation, and, in some cases, these abuses are seen as amounting to 'unfree' recruitment, one of ILO's three indicators of forced labour (65, 68, 69). In 2009, the ILO's third Global Report on Forced Labour stated that "many present-day arrangements for recruiting temporary workers display serious deficiencies . . . these derive from loopholes in the existing labour laws, which fail to articulate the respective responsibilities of recruiting agents and final employers in providing safeguards against abusive practices, including forced labour." (70) High recruitment fees are conceived as a primary mechanism that links recruitment to forced labour because these fees lead to debts that constrain a worker's freedoms at destination.

In response, international and inter-agency stakeholder groups, including groups like the ILO and IOM, are investing heavily in establishing a global model of 'fair recruitment'[4] to promote safe migration into decent work (65, 69, 71, 72). The ILO defines fair recruitment as "recruitment carried out within the law, in line with international labour standards, and with respect for human rights, without discrimination." (11) The ILO's General Principals for Fair Recruitment include, for example, promoting freedom of association and collective bargaining, providing transparent and accurate information about employment conditions, and, importantly, eliminating recruitment fees and adhering to an 'employer pays principle' (ibid.). Table 1 summarises the objectives of ILO's Fair

[4] 'Fair recruitment' will be the terminology used in this thesis to describe a wider body of policy and programmatic work sometimes synonymously described as 'responsible recruitment' or 'ethical recruitment'.

Recruitment Initiative and gives some examples of the kinds of work being undertaken to achieve the objectives (73).

Table 1. ILO's 3-pronged approach to Fair Recruitment, ILO Factsheet (2017) (73)

Objective 1 Establishing fair recruitment corridors to prevent exploitation of migrant workers	Objective 2 Providing migrant workers with access to reliable information and services	Objective 3 Disseminate and enhance global knowledge about recruitment and engagement with the media
Pilot test a fair recruitment model from Nepal to Jordan in the apparel industry	Design and test a web tool to monitor private employment agencies in collaboration with ITUC	Develop and adopt through tripartite process fair recruitment principles and operational guidelines
Promote fair recruitment practices from the Philippines to Hong Kong in the domestic work sector	Empowerment of workers' organizations to support migrant workers throughout the recruitment process	Collaborate with the media to investigate recruitment abuses and promote solutions proposed in ILO research.
Support fair recruitment practices in Tunisia	Development of a violation reporting system in partnership with MFA and strengthening of access to remedies	

The Freedom Fund, an international non-governmental anti-trafficking organization, recently commissioned LSHTM researchers Cathy Zimmerman and Joanna Busza to oversee a review of 'responsible recruitment' initiatives with the aim of identifying promising practices. This review highlighted government- and NGO- led recruitment interventions, including, for example, pre-migration knowledge building, recruitment agency regulation, and migration corridor memoranda of understanding (MOUs) or bilateral agreements (74). However, this review did not find any rigorous evaluations of these initiatives, only anecdotal evidence of promising practices (74).

One challenge to 'fair recruitment' is that the definitional boundaries of 'recruiters' and 'recruitment' practices are still relatively opaque and highly context dependent (14, 61, 74). Furthermore, we know very little about migration decision-making and which preferences or constraints shape how migrants choose recruiters or other subsets of intermediaries. Fair

recruitment initiatives often narrowly address recruitment within *legal* migration pathways and, as a result, may fail to address the needs of migrants who are navigating highly irregular corridors and porous border crossings, such as labour migration between Myanmar and Thailand.

1.3 Myanmar-Thailand migration corridor

In the Southeast Asian region known as the Association of Southeast Asian Nations[5] (ASEAN), two-thirds of international migrants are intra-regional migrants, most of whom relocated within the Greater Mekong[6] subregion (Figure 3). Within the ASEAN region, Myanmar and Thailand respectively are the highest net-*sending* and net-*receiving* countries and, together, the most frequented ASEAN corridor (75).[7]

Figure 3. Greater Mekong subregion: Myanmar-Thailand migration corridor

For the past four decades, multiple migration drivers, both 'push' and 'pull' factors, have contributed to the 'mixed flows'[8] of labour migrants, environmental migrants, refugees, unaccompanied minors, and other migrant groups in the Myanmar-Thailand corridor (57). In the 1980s,

[5] The ASEAN region is a regional grouping within Southeast Asia that promotes economic, political, and security cooperation among its ten members: Brunei, Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, the Philippines, Singapore, Thailand, and Vietnam.
[6] The Greater Mekong subregion includes Cambodia, Lao PDR, Myanmar, Thailand, and Vietnam.
[7] Approximate 2.2 million emigrants leave Myanmar every year and approximately 3.5 million immigrants enter Thailand every year, the majority of whom are from Myanmar.
[8] IOM defines 'mixed flows' as, "complex migratory population movements that include refugees, asylum-seekers, economic migrants and other migrants, as opposed to migratory population movements that consist entirely of one category of migrants." (76)

economic and political unrest in Myanmar, including an eventual military coup in 1988 (akin to the ongoing 2021 Myanmar coup today), forced many to flee Myanmar and cross the porous 1,300-mile border with Thailand to seek asylum (77). Soon after, in the 1990s, Thailand initiated systematic efforts to recruit foreign labour from poorer neighbouring countries to help fuel industrial growth (78). Since that time, Thailand has established itself as an emerging-economy, owing much of its success to its profitable export of goods and services (79). Thailand's high-export sectors, such as manufacturing and seafood, have relied heavily on 'cheap' migrant labour to maintain high gross margins, while still satisfying international demand for low-cost goods (78). The economic and political drivers in Myanmar coupled with labour demands in Thailand have established a steady flow of migration between these states (80).

1.3.1 Myanmar migrants' motivations and means

A recent household survey on Myanmar migration trends, led by the University of Sussex, reported that the most frequently cited motivation to migrate was to improve employment or income (81). For many migrants, livelihood motivations are also influenced by a myriad of economic and social drivers, including, for example, pervasive unemployment, household debt, escaping intimate partner violence, migration norms among peer groups, or even aspirations to purchase new property or luxury goods beyond their current means (81).

An ILO study on intra-ASEAN labour migration, found that Myanmar respondents paid $587 USD on average to migrate and about half of these respondents (52%) had to borrow the full cost to migrate (82). The same study reported that it took individuals approximately 10 months to pay off these debts, in part, due to low pay at destination (82).

1.3.2 Myanmar migrants' experiences of labour exploitation in Thailand

According to the Global Slavery Index (GSI), there are approximately 610,000 individuals in situations of modern slavery in Thailand, predominantly in the

form of labour trafficking or sexual exploitation (83, 84). Numerous peer-reviewed studies and NGO reports indicate that a disproportionate number of those victims are migrant workers from Myanmar (83, 85–88). For example, in the previously mentioned STEAM study, Kiss and colleagues found that 28% of the human trafficking survivors they interviewed in Thailand were Myanmar migrants (58). Men from Myanmar are more often trafficked into fishing, construction, and manufacturing work, whereas women and girls are more commonly trafficked into the garment sector or domestic services (86).

Myanmar workers that do not experience these more severe forms of labour exploitation (i.e., trafficking, or modern slavery) are still highly likely to experience repeated wage theft. The ILO reported that Myanmar migrants in Thailand make $176 USD on average monthly, which is approximately two-thirds of the legal Thai minimum wage and the lowest monthly income of all ASEAN migrant groups in Thailand, despite Myanmar migrants working the longest hours (82).

Many Myanmar migrants also face unfair recruitment practices before or during migration, including migrants using the recommended formal channels. For example, the ILO reports that 22% of the Myanmar migrants they interviewed had a written contract for work in Thailand and nearly half of these individuals (43%) did not get the job they were promised (82). Another ILO study on recruitment costs in the ASEAN region, reported that despite Thailand's ban on charging recruitment fees to migrants, most migrants using recruiters were still paying high fees, sometimes incurred on both the Myanmar and Thailand sides (89).

1.3.3 National and bilateral labour immigration and trafficking policy

The immigration policies that govern the Myanmar-Thailand corridor are notoriously opaque and subject to regular updates (57, 80, 83). Table 2 presents a summary of the relevant immigration and anti-trafficking policies enacted in the past four decades. Thai immigration management and policy

has been described as especially unpredictable, “oscillating between amnesty and crackdown.” (83) Thailand’s most recent ‘amnesty’ in 2016-2018 included a National Verification process which called for all irregular migrants to register for proper identification and work permits – a nearly impossible bureaucratic process with long waits, which resulted in low completion rates (83, 90).

In 2003, Thailand and Myanmar signed a Memorandum of Understanding (MOU), revised in 2016, which is now the bedrock for current labour migration policy in the corridor and includes a required step of formal recruitment through registered recruitment agencies. In the MOU system, migrants are supposed to receive written contracts and work permits that are valid for two years with possible renewal. These documents are linked to a designated employer and migrants must complete a formal resignation process with that employer if they want to change employers. Despite threats of deportation and high fines for migrating outside of the MOU process, it is estimated that close to 80% of Myanmar migrants are still using irregular channels to migrate to Thailand, often facilitated by social networks or informal intermediaries (63, 82, 89, 91).

Even migrants that choose the MOU channel often rely on informal intermediaries to help them navigate the administrative processes (91). Various migrant organizations have reported that it is unreasonable to expect migrants to keep track of the many policy changes and to understand their options (83, 92). Recent research by the NGO Verité concluded that the MOU process has been unsuccessful in its attempt to replace irregular migration pathways because migrants find the process to be too complicated, costly, and time intensive (91). The report states that stakeholder-led promotion of this legal migration channel is motivated, in part, by the assumption that increased regulation will protect workers, but this assumption was not supported by empirical evidence (91).

Table 2. Myanmar-Thailand labour migration policies

Policy	Year (revised)	Summary
Thailand's Immigration Act	1979	Enforces that any immigrant who enters Thailand without a visa and/or acts in breach of immigration law is illegal and may be deported and or penalised by other sanctions. (57, 80)
Thailand's Foreign Employment Act	1978	Requires that a foreign immigrant must have a work permit to work in Thailand and he/she can only be employed in work activities designated by law by the relevant authorities, currently the Ministry of Labour. (57, 80)
Myanmar's Law Relating to Overseas Employment	1999	Law with the objective to ensure workers do not lose any rights or privileges entitled to them. The law also requires overarching institutional structures and recruitment agencies to actively support and protect Myanmar workers abroad and extends some of Myanmar migrant workers' rights abroad. (57, 80)
Bangkok Declaration of Irregular Migration (ASEAN-wide declaration)	1999	Declaration that highlighted the importance of cooperative management of labour migration between countries of origin and destination in the Asia and Pacific region and set the groundwork for the future bilateral MOUs between Thailand and Cambodia, the Lao People's Democratic Republic, and Myanmar. (57, 80)
Thailand and Myanmar's MOU on the Employment of Migrant Workers	2003 (2016)	Bilateral agreement and guideline for the protection and return of workers to their respective countries upon completion or termination of contracts in Thailand. The agreement includes guidelines on: worker protection in accordance with domestic laws in their respective country; equitable and non-discriminatory wages; employment contract length; medical provisions; changing employer; illegal recruitment; and skill provision. (80)
Thailand-Myanmar MOU on the Cooperation against Trafficking in Persons in the Greater Mekong	2004	Bilateral agreement with the principal objective to enhance regional capacity to combat human trafficking. (80)
ASEAN Declaration on Protection and Promotion of the Rights of Migrant Workers	2007	Declaration that makes strong human rights statements and emphasises the duty of origin states to provide economic opportunities and to protect their citizens (Article 12), and for destination countries to protect the labour rights of migrant workers (Article 5-10). (57, 80)
Thailand's Anti-Trafficking in Persons Act	2008 (2015) (2017)	Law that criminally prohibits all forms of trafficking in persons and prescribes penalties that are sufficiently stringent and that are commensurate with penalties prescribed for other grave crimes. (93)
ASEAN Consensus on the Protection and Promotion of the Rights of Migrant Workers	2017	Declaration that builds on the 2007 ASEAN Declaration on Protection and Promotion of the Rights of Migrant Workers and calls on ASEAN Member States to promote the full potential and dignity of migrant workers, and place certain obligations in this respect on receiving and sending States. (94)
Thailand's Royal Ordinance on the Management of Foreign Workers Employment	2017 (2018)	Consolidating Thailand's laws on recruitment and employment of migrant workers, it was hoped that a unified law would bring greater clarity and coherency to Thailand's largely ad hoc legal framework on labour migration. However, what the law made most clear was that strict enforcement against irregular migration was to be used as the key policy approach to convince migrants to use regular channels. (57, 80)

1.3.4 Brief note on the scope of the study target population

Since the early political unrest and military coup in the 1980s, Myanmar has continued to endure protracted conflicts, both ethnic conflicts as well as state-sanctioned violence against minority and unrecognised 'stateless' groups, such as the Rohingya. On 1 February 2021, head of the Myanmar military, General Min Aung Hlaing, staged a second military coup on the heels of a national election. The coup is an act of illegitimate defiance against the victory of the National League for Democracy (NLD), led by Ms. Aung San Suu Kyi (95). The coup quickly became and continues to be violent in response to peaceful pro-democracy protests and has now left more than 600 dead, thousands injured, and thousands as political prisoners (95). The ongoing coup has forced many minority groups, activists, defecting police officers, and fearful citizens to flee Myanmar and seek asylum in bordering countries, including Thailand (96).

For decades, Thailand has housed refugee camps along the border with Myanmar in the Tak region, which is also one of Thailand's designated Special Economic Zones (SEZs). Thailand's SEZs are designated areas for infrastructure development where businesses can receive investment incentives and have easier access to foreign workers (97). A 2015 survey with Myanmar migrants residing in Thailand's border areas found that 45% of individuals residing in the refugee camps had some form of employment, mostly as farmers or day labourers (98). This concurs with a growing body of research that questions the usefulness of the refugee-labour migrant dichotomy in some contexts and challenges the application of this migrant framework to guide policy and programmatic mandates. In some geographies the distinction between involuntary and voluntary migration is hazy and migrants' dynamic motivations and goals may blur these distinctions further.

Such overlaps form a highly complex mixed-migration corridor between Myanmar and Thailand. However, given the magnitude of the subject of

mixed-migration, some of this phenomenon is outside of the scope of this thesis and this research has attempted to focus on the patterns and dynamics of migration trajectories that were initiated voluntarily with the primary aim of finding work.

1.4 Study rationale and aim

Informed by the 2015 safer migration reviews (14) and the emerging body of literature on migration mediation (61, 63, 64, 74), this study was designed to address gaps in safer migration and fair recruitment intervention research. These gaps are both empirical and methodological, so this study was conceived to address both empirical and methodological aims and objectives.

1.4.1 Empirical aim

The empirical aim of this thesis is to describe the complex and dynamic system of actors that facilitate Myanmar-Thailand labour migration. This work focuses primarily on the distinct roles of all intermediary and social actors involved in migration decision-making, planning, and execution processes.

This work also responds to the conclusion in Katharine Jones literature review on migration mediation, which recommends that future research on intermediaries should:

> "explore their role within a broader context of the process of migration . . . research all the different actors involved in facilitating migration . . . focus on what intermediaries do rather than only who they are . . . [and research] the linkages between various actors in the migration system." (61, p. 15)

The empirical objectives for this study include:

Objective 1. Map the individual migration networks by identifying all the different actors involved at each stage of the migration process, including how the links between migrants, social contacts, intermediary actors, and employers develop.

Objective 2. Describe the dynamic actions and interactions in the migration networks throughout the migration processes, including, for example, information sharing, decision-making, planning, and facilitation.

Objective 3. Explore how these emergent migration networks influence and are influenced by migration pathway decisions.

1.4.2 Methodological aim

Additionally, this thesis aims to advance the use of complex systems theory and computational social science for safer migration intervention research. To meet this aim, this study set the following methodological objectives:

Objective 4. Review the use of agent-based modelling (ABM) for research on migration, labour exploitation, and 'modern slavery' to assess the methodological opportunities and limitations.

Objective 5. Develop new visual and interactive tools for participatory network mapping with migrants to improve systematic collection of relational data in challenging fieldwork settings and new tools for mixed methods social network analysis (MMSNA).

Objective 6. Design an empirically-based ABM on migration networks and pathways that is informed by MMSNA and migration theory.

1.4.3 Applied aim

Lastly, informed by the empirical outputs of Objectives 1-3 and using the methodological learning and outputs from Objectives 4-6, this thesis also aimed to produce a first-of-its-kind ABM to inform safer migration interventions. The final objective of this thesis is to:

Objective 7. Simulate the dynamic process of Myanmar-Thailand labour migration and preliminarily explore how migration networks and pathways influence individual experiences of precarity at destination.

Chapter 2. Theoretical and Conceptual Frameworks

This thesis uses **complex realism** as an ontology to frame migration systems, and an epistemology to guide the research questions and choice of empirical methods. **Section 2.1** provides a brief introduction to a complex-realist philosophical approach to empirical research.[9] **Section 2.2** uses complex systems thinking to synthesise a multi-level migration system theoretical framework to inform the study's conceptual framework. **Section 2.3** presents the original complex low-wage labour migration system conceptual framework developed for this thesis and used to guide the study design.

[9] This chapter was informed primarily by two key texts and made use of the references within these texts: 1) Reed and Harvey's 1992 paper *The New Science and the Old: Complexity and Realism in the Social Sciences* (99); and 2) Byrne and Callaghan's 2014 book *Complexity Theory and the Social Sciences: State of the art* (100).

2.1 Complex realism and complexity theory

Complex realism is a convergence of realist approaches and complexity theory (101).[10] Realism is a scientific paradigm that gives equal consideration to what *does* exist and what we can feasibly *know* about what exists (102). Complex realism is akin to Roy Bhaskar' critical realism, an increasingly common philosophical ontology adopted by social scientists (99). A critical realist approach asks what we can assume about reality given what we have observed from an experiment (i.e., retroductive reasoning) (103). Critical realism posits that empirical research should aim to identify causal mechanisms (not 'universal laws') and consider the role of agency *and* structure in shaping human behaviour, instead of assuming a position that agency *or* structure determine individuals' outcomes (103).

The addition of *complexity theory* is what distinguishes complex from critical realism (101). David Bryne argues that complexity 'theory' is better appreciated as a "framework for understanding" to explore the social world, which is a collection of complex systems (i.e., complex systems thinking). (100) Complex systems are multi-level, often nested, systems consisting of many heterogenous entities, interactions, and dependencies (104). A complex system is characterised by its dynamic properties (i.e., changes over time), feedbacks, adaptations, and emergent phenomena (104). Complex realism is a framework for researching causal mechanisms in complex systems.

Reed and Harvey contend that a philosophical ontology "[shows] the scientist in broad outline what the world and his or her knowledge of it should look like . . . however, [it] only describes the boundaries of an intellectual continent, not its surface details. The task of filling in the gaps on

[10] Complex realism sits at the convergence of social theory and natural sciences, inspired by thermodynamic 'open systems', which present an ontological structure that narrows the gap segregating understanding of the physical universe, living organisms, and society (99). This thesis focuses on the study of complexity within social systems.

the philosophical map belongs to the scientist." (99) This thesis uses complex realism as a theoretical framework to sketch the outlines of a complex system of migration and formulate questions about that system's causal mechanisms. The outputs of the empirical objectives of this thesis fill in the 'surface details' of that system – its entities, interactions, and processes.

2.2 Multi-level migration system – a theoretical framework

A realist approach always considers the theories that shape our interpretations of empirical evidence (i.e., it is a theory-dependent approach) (103). From a *complex* realist approach, this thesis synthesises relevant migration theories using a complex system framing.

Sociologist and migration theorist, Douglas Massey, posits that:

> "a full understanding of contemporary migration processes will not be achieved by relying on the tools of one discipline alone or by focusing on a single level of analysis. Rather, their complex, multifaceted nature requires a sophisticated theory that incorporates a variety of perspectives, levels and assumptions." (105, p. 432)

Massey and his contemporaries, Caroline Brettell and James Hollifield, suggest that interdisciplinary migration research creates an opportunity to use conceptual tools at different levels of analysis (e.g., micro-meso-macro) – a suggestion that is highly compatible to a complex realist approach (105, 106). Together, multi-level migration theories can offer insightful frameworks to inform complex systems migration research, such as this thesis. Figure 4 summarises the **multi-level migration system theoretical framework** developed as part of this thesis to guide the formation of a conceptual framework for the study design (Section 2.3). The framework depict multiple levels of migration theory (micro-meso-macro) and an arrow representing inter-level interactions and feedbacks across the levels which make the content of each level change and adapt over time (e.g., migration decision-making is not a static process, and it is also not executed in 'isolation' from other levels, such as the networks that a migrant is situated within).

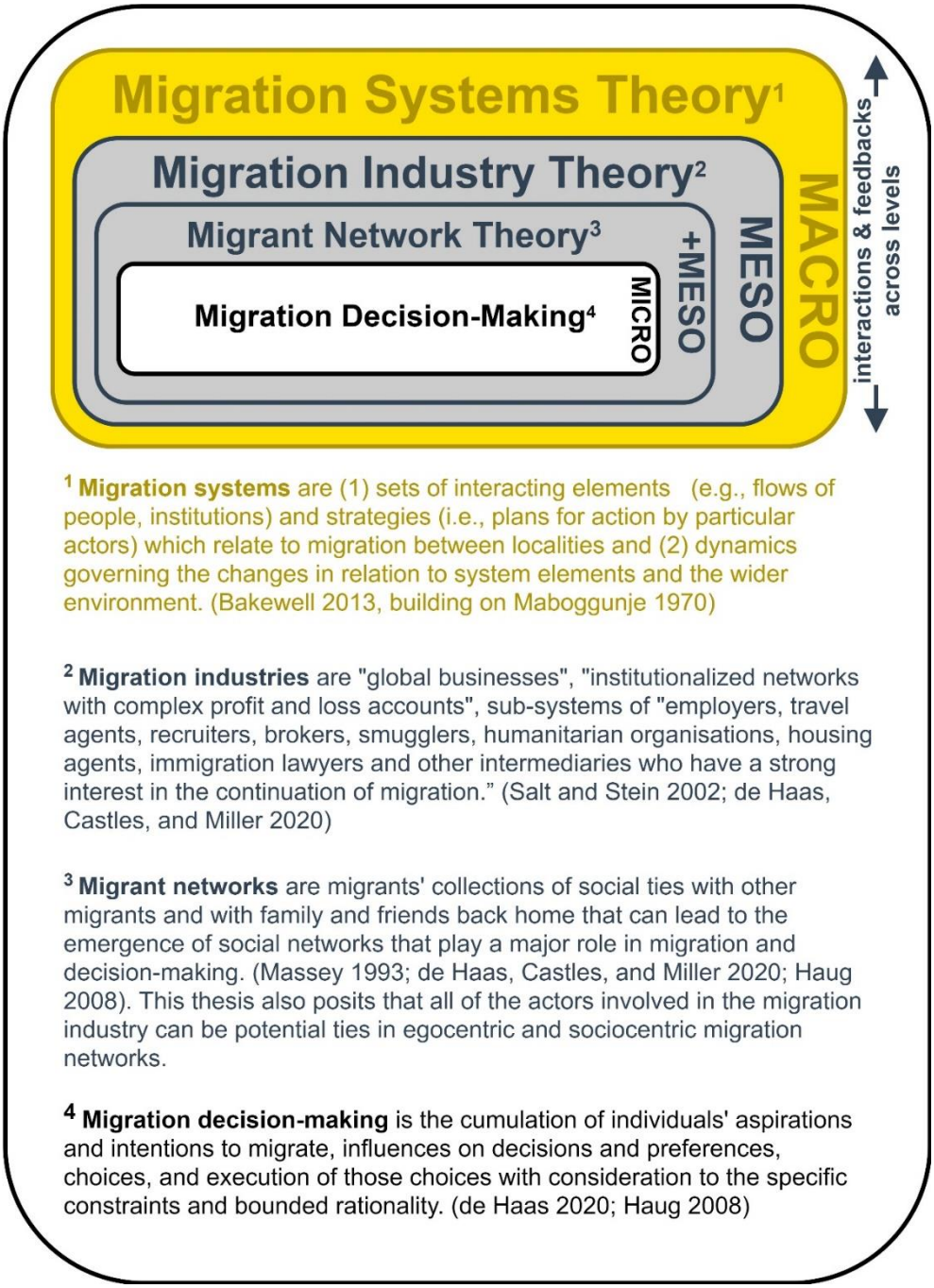

Figure 4. Multi-level migration system theoretical framework

Macro-theory. Senior Migration and Development Lecturer Oliver Bakewell, proposes a reformulated migration system theory (107) building on Mabogunje's similar work in 1970 (108). Bakewell defines a migration system as one that has:

> "(1) a set of interacting elements—including flows of people, ideas and goods, institutions . . . and strategies as in plans for action by particular actors—which relate to the migration between localities; and
>
> (2) dynamics governing the way in which the elements change in relation to changes in both these system elements (feedback mechanisms) and in the wider environment." (107, p. 310)

This theory supports the case for using a *complex* realist approach and complex systems methodologies that can feasibly explore system interactions and dynamics. Bakewell's definition suggests possible system features ('interacting elements', 'strategies', 'dynamics', 'feedbacks', 'environment') to incorporate into future conceptual or empirical work that addresses migration systems.

Meso-theories. Migration industry theory and migration network theory describe meso-level 'elements' of the migration system. Renowned migration scholars, Hein de Haas, Stephen Castles, and Mark Miller, state that a 'migration industry' can consist of, "employers, travel agents, recruiters, brokers, smugglers, humanitarian organisations, housing agents, immigration lawyers and other intermediaries who have a strong interest in the continuation of migration." (109) John Salt and Jeremy Stein describe migration as, "a global business which has both legitimate and illegitimate sides . . . a system of institutionalised networks with complex profit and loss." (110, p. 468)

Migration networks are formations of social links between migrants and their family and friends back home. (109) Empirical evidence indicates that, in many contexts, migration networks (i.e., social capital) play a critical role in facilitating migration flows (60, 111–113, 113). Most research on

'migration networks' has focused narrowly on the role of social networks (i.e., family, friends, community) and rarely on the role of intermediary networks, such as smugglers (64), or the overlap of social and intermediary networks (61). An emerging body of research highlights that intermediaries (e.g., brokers, recruiters, 'middlemen') are key influencers across all levels of the migration system and are often embedded within multiple industries and networks (61).

Micro-behaviours. A single theory would struggle to explain all possible micro-behaviours exhibited by actors in a migration system. The micro-level of this multi-level theoretical framework focuses on migration decision-making as a key micro-influence on individual migration processes, the empirical focus of this thesis.

Individual migrations are often conceptualised as trajectories (or 'pathways'). Stefanie Kley, sociologist and economist, adapted the Rubicon model of 'action phases' to the behavioural stages of migration (Figure 5) (114). Kley's model depicts four migration stages isolated by decision or action points. The stages include considering ('pre-decisional'), planning ('pre-actional'), and realizing ('actional') migration, and living at destination ('post-actional'). Zimmerman, Kiss, and Hossain, also consider migration 'stages' as a way to conceptualise the typical actions, opportunities, or vulnerabilities at various points in migration (5). Framing migration 'pathways' by stages offers one way to explore and organise the range of decision-making and decision-making consequences that take place across the full trajectory of a migration.

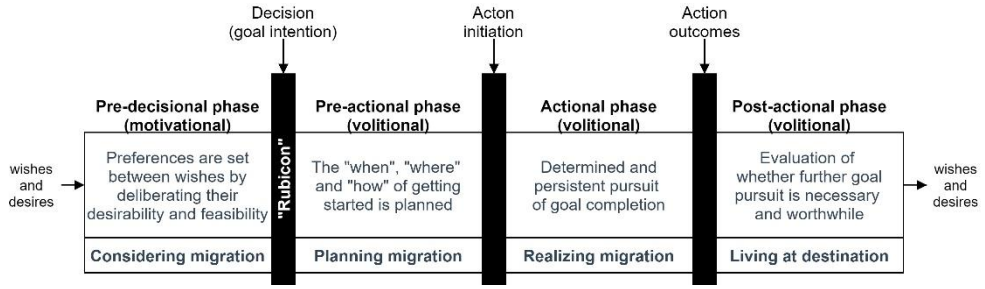

Figure 5. Kley's Rubicon model of planned action for migration (114)

Hein de Haas argues that "the main conceptual problem of conventional theoretical accounts of migration remains their inability to meaningfully conceptualise how individual migrants and groups of migrants exert agency within broader structural constraints."(115) De Haas offers a theory to bridge the agency versus structure debate (micro vs. macro) with key relevance to migration decision-making (115). De Hass's 'aspiration-capabilities framework' conceptualises migration as, "a function of people's capabilities and aspirations to migrate within given sets of perceived geographical opportunity structures." (115) That is, migrants' decisions to act, regardless of the motivation to migrate, are restricted by what is feasible given the broader meso- and macro- realities.

While there is not yet a robust theory on migration decision-making, empirical research provides preliminary insights on this individualised process, including:

- economic incentives explain some but not all motivations to migrate (60);
- the decision to migrate is often a household, not individual, decision (The New Economics of Labour Migration Theory) (109);
- migration decisions are made under a range of uncertainties, with imperfect and incomplete information (116);
- migration is a 'complex choice' with multiple objects and subjects of decision making at different stages (117); and
- the decision to migrate irregularly is often a means to circumvent unfavourable state systems, but also an emergent property of entrepreneurial initiatives within migrant networks (118).

In line with a realist approach, Castles suggests that migration theory and methods should be "able to incorporate both structure [macro-social] and agency [micro-social]." (119) Merging **macro- and meso-** migration theories depicts migration as a 'system of systems'. Meso-level theories, such as migration industry and migration network theory, account for potential 'touchpoints' between structure and agency. Empirical insights on **micro-behaviours**, such as migration decision making, indicate that individual actions and interactions exist within **meso-level** networks and industries (e.g., socially motivated migration, household decision-making, etc.). This multi-level migration system theoretical framework facilitates our understanding of how a migration process is influenced by entities, interactions, and dynamics at multiple levels. For example, social networks (**meso**) emerge from individual interactions and decisions (**micro**), but in turn, these networks establish international migration corridors (**macro**) that prompt new immigration policies (**more macro**), which then cause system feedbacks that influence social networks (**meso**) and individual decision-makers (**micro**).

2.3 Complex low-wage labour migration system – a conceptual framework

The theoretical framework (Figure 4) informed the development of a **complex low-wage labour migration system conceptual framework** to guide the study design (Figure 6). To my knowledge, this combination of theories has not been used to explore labour migration. Figure 6 presents a system framework that sketches the micro-meso-macro levels, entities at each level, and relationships between levels. The framework illustrates the dynamic process of migration that is influenced by the multi-level entities and their interactions. Specifically, Figure 6 depicts the linkage between the actors, networks, pathways, and outcomes in a migration process:

1. **Migration actors (micro):**
   - **Migrant:** a migrating actor with individual attributes (e.g., demographics, history, resources, motivations, preferences, etc.)
   - **Network actors:** various 'other' actors (i.e., social contacts, intermediaries, employers) involved in the migration process
   - **Actor-Actor links:** relationships (e.g., family, co-workers) and interactions (e.g., influences, offers, payments) between a migrant and network actors or between multiple network actors
2. **Migration networks (meso):** the dynamic group of linked actors involved in the migration process through their behaviours and decisions
3. **Migration pathway (micro):** the set of characteristics or events that describe the full migration process (e.g., network involvement, initiation of migration, planning, financing, transit, destination, employment)
4. **Migration outcomes (micro):** the migrant's experiences at destination (e.g., precarity, health and wellbeing, employment conditions, income and changes to wealth, skill building, and level of satisfaction, etc.) which produce feedbacks that can influence migrants and network actors
5. **Migration environment and temporality (macro):** the broader context and dynamics (e.g., geography, labour market, time) that influence the system entities (i.e., actors, network, pathway, outcomes)

This conceptual framework[11] outlined the key areas for data collection and illustrates the need for methods that can adequately capture system interactions, dynamics, and feedbacks.

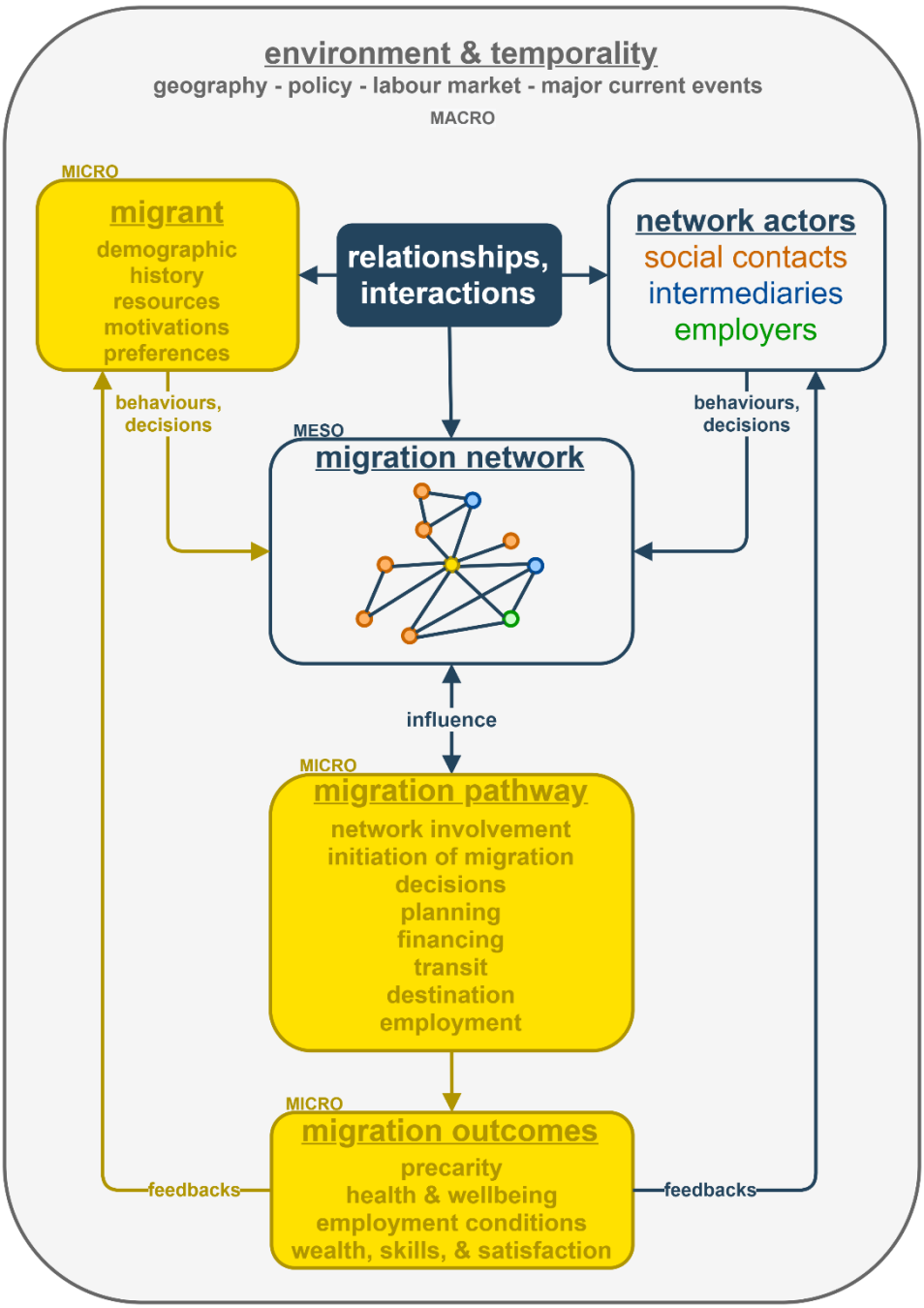

Figure 6. Complex low-wage labour migration system conceptual framework

[11] See Appendix 2 for earlier iterations of the complex low-wage labour migration system framework.

Chapter 3. Methods

Complex systems researchers, John Miller and Scott Page, contend that many of today's pressing challenges are complex and dynamic problems "awash in a sea of feedbacks" (104). Miller and Page maintain that endeavouring "to understand, and ultimately to harness, such complexity will require a sustained and imaginative effort on the part of researchers across sciences." (104) This thesis addresses complex labour migration challenges through innovative uses of mixed and complex systems methods with an aim to advance interdisciplinary complex systems and computational social science approaches for migration research.

Section 3.1 provides the rationale for a mixed methods empirical study design. **Section 3.2** presents the full methodological framework. **Section 3.3** describes the ethical considerations and approvals for this research. **Section 3.4** is a reflexivity statement that addresses my position as the researcher.

3.1 Rationale for mixed methods approach

A 'mixed methods' approach integrates multiple methods of analysis of structured and unstructured data[12] (120). Jennifer Greene's definition of mixed methods research captures some of the rationale and motivation for using mixed methods in this thesis:

> "Mixed method inquiry is an approach to investigating the social world that ideally involves more than one methodological tradition and thus more than one way of knowing, along with more than one kind of technique for gathering, analysing, and representing human phenomena, all for the purpose of better understanding." (121, p. 119)

A mixed methods approach strategically utilises one method's strength to handle another method's limitations and biases (120, 122). The combined strength of methods enhances insights into the research problem. At times, a mixed methods approach is essential to achieving certain empirical aims with objectives that span different targets of analysis. Migration scholars, Bretell and Hollifield, pose that migration research addressing different units (or 'levels') of analysis, such as distinct micro-, meso-, or macro- questions, need specific types of analysis to address a level (106). For example, measuring prevalence of migration and correlated trends requires representative samples, structured survey data, and statistical methods, whereas exploring the lived-experiences of sub-demographics of migrants requires a more focused sampling frame and qualitative methods. Thus, *multi*-level migration research often warrants the use of multiple methods.

[12] Often 'quant' and 'qual' data are distinguished as the two research paradigms being 'mixed' and are sometimes used synonymously to describe the two types of data. However, because quant. and qual. represent two paradigms of *methodological approaches*, this thesis prefers to describe the data independent from any method of analysis.

This thesis used a mixed methods design[13] in which mixed data collection and mixed methods analysis were completed within the same timeframe and with equal weight given to each type of analysis (123).

The two techniques for data *collection* were conducted concurrently:

1) structured egocentric network mapping and outcome surveys; and
2) unstructured in-depth qualitative interviews.

The two methods for data *analysis* were conducted sequentially, but the mixed methods analysis within each respective method was conducted concurrently:

1) mixed methods social network analysis (MMSNA); and
2) agent-based modelling (ABM) informed by the MMSNA findings.

These individual methods and the overall mixed methods complex system study design are described in more detail in Section 3.2. Table 3 outlines the methods of analysis and outputs for each objective. Each method used both the structured and unstructured datasets. Table 4 outlines how the entities in the **complex low-wage labour migration system framework** (Figure 6) were captured using the two data collection techniques (i.e., structured and unstructured).

[13] There are a variety of mixed methods study designs (i.e., triangulation, embedded, explanatory, exploratory) and describing them all is beyond the scope of this thesis.

Table 3. Thesis objectives, methods, and outputs

	Objective	Methods	Output
Empirical	**1.** Map the individual migration networks by identifying all the different actors involved at each stage of the migration process, including how the links between migrants, social contacts, intermediary actors, and employers develop.	MMSNA	Paper 3 Appendix 6
	2. Describe the dynamic actions and interactions in the migration networks throughout the migration processes, including, for example, information sharing, decision-making, planning, and facilitation.	MMSNA	Paper 3 Appendix 6
	3. Explore how these emergent migration networks influence and are influenced by migration pathway decisions.	MMSNA	Paper 3 Paper 4 Appendix 6-8
Methodological	**4.** Review the use of agent-based modelling (ABM) for research on migration, labour exploitation, and 'modern slavery' to assess the methodological opportunities and limitations.	Systematic literature review	Paper 1 Appendix 4
	5. Develop new visual and interactive tools for participatory network mapping with migrants to improve systematic collection of relational data in challenging fieldwork settings and new tools for mixed methods social network analysis.	Fieldwork notes and piloting	Paper 2 Appendix 5
	6. Design a proof-of-concept empirically-based ABM informed by MMSNA using complex data sources (e.g., datasets that capture heterogenous actors, interactions, dynamics and feedbacks, and possibly across multiple levels).	MMSNA ABM	Paper 4 Appendix 7-8
Applied	**7.** Simulate the dynamic process of Myanmar-Thailand labour migration to preliminarily explore how migration networks and pathways influence individual experiences of precarity at destination.	MMSNA, ABM	Paper 4, Appendix 7-8

Table 4. Describing system entities with structured and unstructured data

Entity	Structured data	Unstructured data
Actors 	demographics, actor type, role (e.g., advised, transported)	motivations to migrate, reputation, preferences
Actor-Actor links 	categorical relationship (family, friends, neighbours etc.)	meeting, exchanges, opinions of each other, level of trust
Network 	network visual: circular nodes for each actor and lines between two relationally 'linked' nodes	network formation over time, migrant's valuation of their network
Pathway 	actor types in network, documents acquired	behaviours, decisions, planning process
Outcomes 	working conditions, compensation, violence, health	new knowledge gained, advice for others, aspirations
Environment 	origin, destination	system-level motivations to migrate (conflict, climate change, high rates of unemployment), policy changes, immigration laws

3.2 Methodological framework

The methodological framework in Figure 7 depicts the three stages of research methods and outputs that sequentially built on each other (red arrows). **Stage 1** was a systematic review of ABMs that simulated migration or modern slavery phenomena to inform future ABM applications (Paper 1). **Stage 2** was a MMSNA study that developed two novel research instruments (Paper 2) and provided new empirical insights on migration networks and pathways (Paper 3). **Stage 3** was an ABM that was methodologically informed by the systematic review (Stage 1) and empirically informed by the MMSNA findings (Stage 2). Together, these methods form a mixed methods complex system study design (Paper 2 of this thesis expands on the rationale for this overall approach). This section summarises each method and sign-posts to the full description of each method in the respective Chapter sections and Appendices.

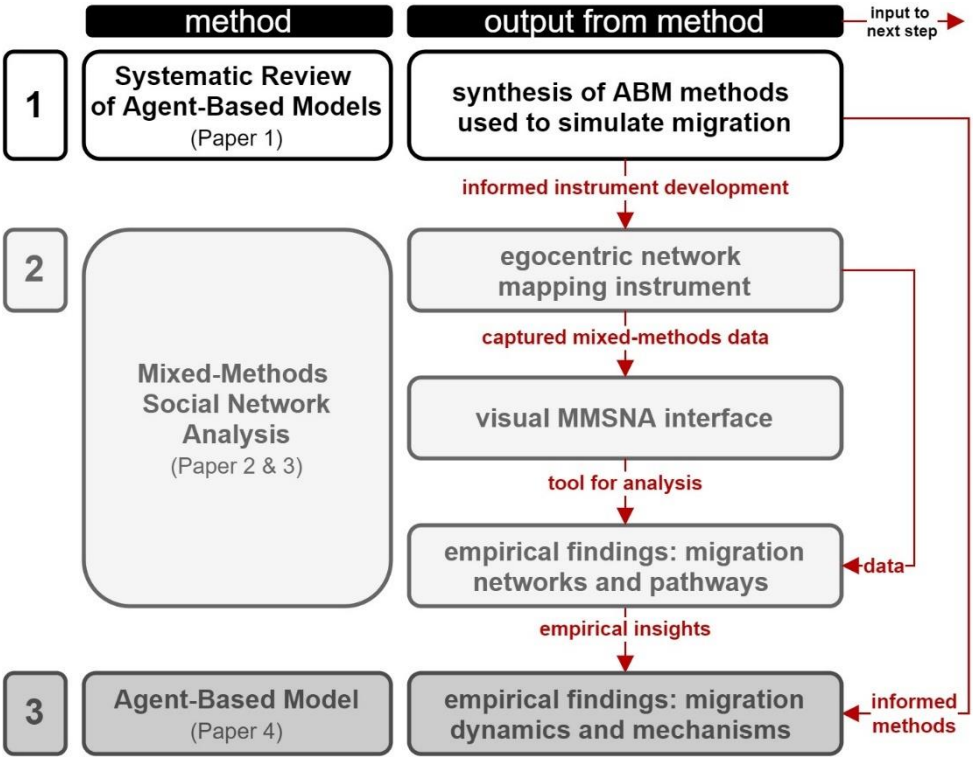

Figure 7. Mixed methods complex system methodological framework

3.2.1 Stage 1: Systematic review of agent-based models

The initial output of this thesis was a systematic review of the state of the art of ABM for research on migration and 'modern slavery' (Objective 4). The aim was to assess the methodological opportunities and limitations and to inform future applications of ABM methods for migration research.

Summary of systematic review methods

The review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) statement (124) and adhered to a strict review protocol that included double-screening. The data extraction tool was informed by the Overview, Design-Concepts and Details + Decision-Making (ODD + D) protocol for ABM development. The extracted data was used to summarise the purpose, design, analysis and validation of the ABMs. Results tables were quality-checked by all co-authors. The condensed review protocol and other supplementary materials are in Appendix 2. The systematic review is Paper 1 (Chapter 4.1).

Systematic review contributions to next steps

The review findings on the empirical inputs and validation of ABMs informed the primary data collection for the MMSNA study (Stage 2). These findings contributed to answering: *What data might help inform our model design? What data could be used to validate the model rules and model outputs?* The review findings on the ABM analysis and evaluation methods informed the analysis plan for the ABM (Stage 3). These findings contributed to answering: *What steps should we take to evaluate this ABM? What types of analysis of the observations are most appropriate to our research questions?* Overall, the review findings contextualised the contribution this thesis is making to the development and application of ABM methods for migration research.

3.2.2 Stage 2: Mixed methods social network analysis

The first phase of the empirical research was a mixed methods social network analysis study that aimed to identify egocentric[14] migration networks, describe migration processes, and explore the linkages between migration networks and pathways (Objectives 1-3). To achieve these objectives, the study design included the development of two visual network tools: 1) a participatory mixed methods network mapping interface that we built to systematically collect network data in a challenging fieldwork setting (e.g., remote locations, time constraints, cross-cultural exchanges, one-time interview opportunities, multiple languages); and 2) a mixed methods network visualisation interface to facilitate convergent mixed methods analysis of the network structures and narratives (Objective 5). While SNA has its roots in mathematical graph theory it is also true that anthropological and sociological studies were amongst some of the first to adopt SNA, but these methods are now most frequently applied and advanced on the new frontier of quantitative 'big data'. However, increasingly social science researchers using network analysis are advocating for the pairing of more traditional structural network analysis with narrative qualitative analysis, known in combination as mixed methods social network analysis (MMSNA).

Summary of the fieldwork, instrument, and data collection

The fieldwork was conducted in three popular destinations for migrant workers in Thailand: Mae Sot near the border, Phang Nga in southern Thailand, and Mahachai just outside of Bangkok (Figure 8). Data collection activities (e.g., recruitment, logistics, service referral) were supported by Freedom Fund's NGO-partners[15]. Interviews were conducted by trained Research Assistants (RAs) who were fluent in Burmese. Eligible participants

[14] Egocentric networks center on one individual ('ego') and include their contacts ('alters') and Alter-Alter links.

[15] Partners: Foundation for Education Development (FED) – Phang Nga, Migrant Assistance Programme (MAP) Foundation – Mae Sot, Migrant Workers Rights Network (MWRN), and Raks Thai Foundation (RTF) – Mahachai.

were adults (18+ years old) from Myanmar that had migrated to Thailand for work in the past 5 years. All participants provided informed consent.

The mixed methods network mapping instrument integrated a participatory egocentric network drawing activity, survey sections, and semi-structured interview guides into a single tablet-based interface. The interface repurposed the visual network map as a probing tool for the semi-structured questions. Appendix 5 includes documentation of the instrument development and pilot interviews. The rationale for this instrument, final methodology, and lessons from the design process are described in Paper 2 (Chapter 4.2).

The data collection captured four types of data: network structures, network node attributes, open-ended migration narratives, and migration outcomes (Figure 9). In addition to tablet-based entry for structured data, interviews were audio recorded, transcribed, and translated from Burmese to English for text-based analysis. All interview data were stored on a password protected hard-drive and a cloud-based secure and encrypted server.

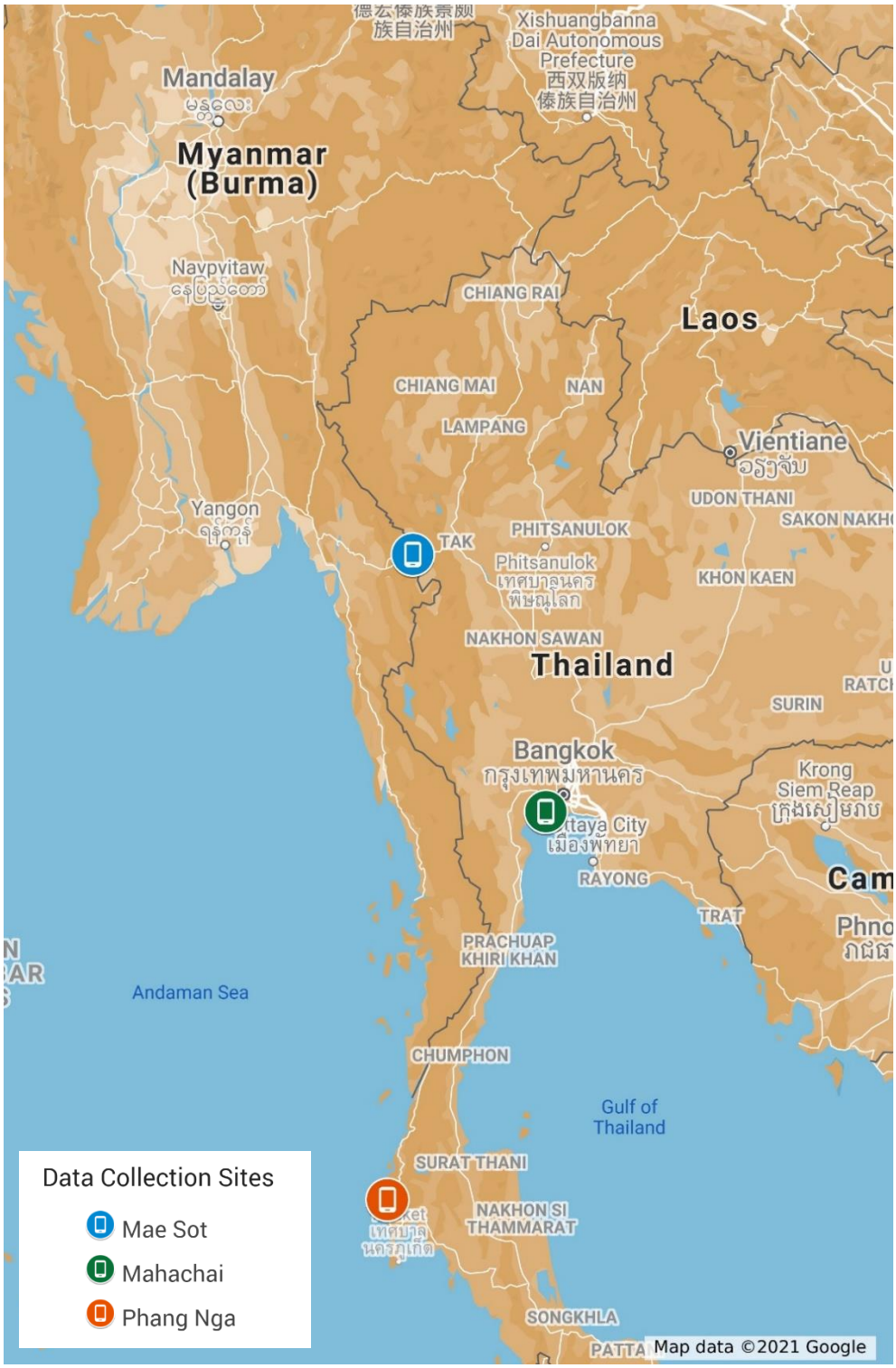

Figure 8. Data collection sites (125)

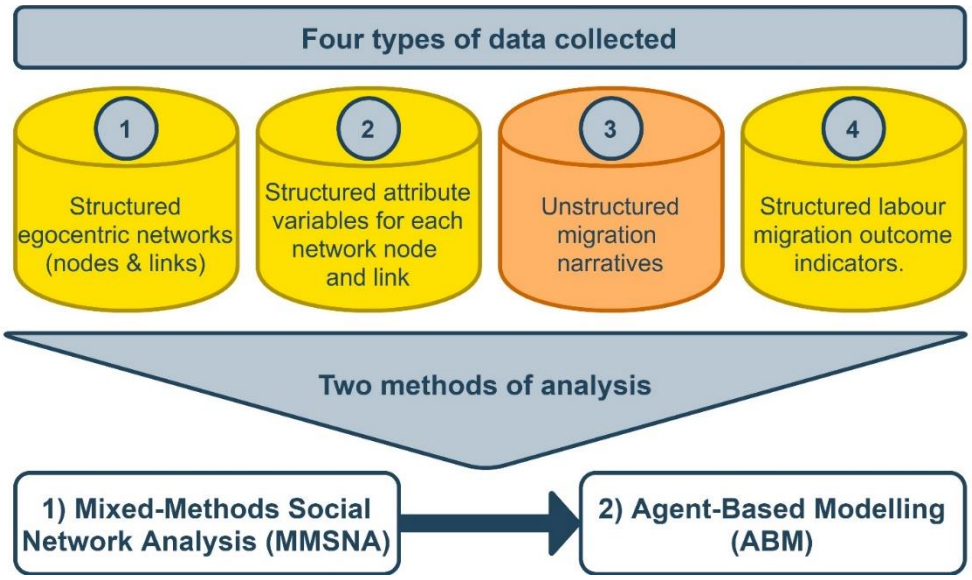

Figure 9. Mixed methods data collection and analysis

Summary of MMSNA methods

Mixed methods is a suitable approach to SNA because networks are *both* structure and process. As Nick Crossley, expert in MMSNA, explains, "network structure is not the whole story . . . we need to supplement methods of formal network analysis with qualitative observations about what is 'going on' within a network'" (126). Qualitative methods can identify network dynamics and mechanisms (127).

Each interview transcript was analysed side-by-side with the network structure (i.e., convergent analysis). Thematic qualitative coding was conducted using NVivo[16] alongside a novel mixed methods data visualisation interface. The analysis used a comparative case-based approach by first exploring individual migration network narratives to describe the process and mechanisms in a single migration (a 'case'), and then comparing emergent themes across all cases (128). A full description of the MMSNA is in Paper 3 (Chapter 4.3).

[16] NVivo is a computer software package produced by QSR International designed for qualitative researchers to organise, analyse and find insights in unstructured data.

Contribution of MMSNA outputs to next steps

As Figure 9 illustrates, the empirical insights from the MMSNA were used to inform the design and analysis of the ABM (Stage 3). MMSNA was able to capture key features that were translated into the ABM design – namely the 'agents' (network nodes), 'agent properties' (node attributes), and the rules of behaviour (network narrative).

3.2.3 Stage 3: Agent-based model

The second phase of the empirical research, third stage in the methodological framework, refer back to Figure 7, aimed to describe the dynamics of the Myanmar-Thailand labour migration system and to preliminary explore the causal links between migration networks, pathways, and outcomes (Objective 7). To achieve this, an empirically informed ABM was used to simulate the dynamic behaviours and interactions in the migration system and observe migration outcomes (Objectives 6-7).

Summary of ABM methods

The MMSNA findings informed the agent and environment entities (i.e., types of actors, geographic locations, etc.) and the agent rules (decisions, interactions, etc.). The nature and dynamics of the rules were primarily informed by the qualitative thematic analysis and the parameters of those rules were calibrated using the quantitative findings and other published research on Myanmar migration trends, such as the Sussex Migration Centre's 'CHIME' study (81). The model was validated in sub-model phases (i.e., checked for errors and unintentional assumptions in the model code). The analysis compared the dynamics of outcomes of different migration pathways and the system's emergent network across three model scenarios. The scenarios were chosen based on their relevance for ongoing 'fair recruitment' interventions, such as the International Labour Organization's 'Guidelines for Fair Recruitment' (11). The model was evaluated by testing the sensitivity of model observations to changes in two key model attributes and by validating the model rules and patterns. The model rules were

validated using partitioned interviews from the MMSNA study (i.e., 15% of the interviews not included in the primary analysis) and the model patterns were validated using relevant studies on Myanmar-Thailand migration trends. Appendix 7 presents the ODD+2D protocol that documents the entire ABM development. The ABM methods are also described in Paper 4 (Chapter 4.4).

3.3 Ethics

3.3.1 Ethical procedures

This study adhered to the ethical and safety protocols advised by *The WHO Ethical and Safety Recommendations for Interviewing Trafficked Women* (129). As advised by the guidance document, this research prioritised:

- exceptional clarity about the optional nature of study participation;
- privacy during interviews;
- full and informed consent to specified use of data;
- guaranteed anonymity of data;
- sensitivity to signs of distress during the interview to avoid re-traumatising individuals with past experiences of violence or exploitation; and
- participant access to referral services.

The research team completed an intensive training session on all ethical and safety procedures. The NGO research partners provided additional ethical and safety considerations for the local context and were available to provide additional support to both the RAs and study participants during the fieldwork.

3.3.2 Informed consent

The written informed consent form was translated into Burmese and used accessible language to explain the nature of the study, interview process, data usage and management, and ethical procedures. The consent preamble assured the interviewee that the research was not affiliated with any government or immigration department and that their answers would not directly impact their migration status, employment, or any services they were receiving from partner organisations. At the start of the interview, the interviewer read the informed consent form aloud and gave the option for the interviewee to read along or on their own before signing. In cases where participants were unable or resistant to signing their name, they could sign with their initials or any symbol marking (e.g., 'x'). The consent form highlighted the option to pause or stop the interview at any time. Each

interview informed consent was checked to ensure protocols had been followed before the data was used for analysis.

3.3.3 Data storage, security, and access

Interview data, including the signed informed consent forms, were collected and stored using tablets and digital audio recorders (e.g., MP3). Tablet-based data collection was conducted using LSHTM's recommended data collection software, Open Data Kit (ODK). Each respondent was assigned a unique participant identification (PID) number to link together their interview materials without using their name in order to protect anonymity and confidentiality. A single password-protected document stored the matched names and PIDs on an encrypted server to provide proof of informed consent for each interview.

During fieldwork, data was safely stored in digital format in three locations as back-up (LSHTM remote secure server, KeyBase end-to-end encrypted cloud-based storage software, password protected local hard drive).

Access to the data was granted exclusively to the researcher team, including the transcribers and translators, who all signed non-disclosure agreements (NDAs). All data was encrypted to an appropriate standard before being transferred between research team members.

3.3.4. Ethical approvals

The study protocol and instruments were approved by two institutional review boards (IRB), the London School of Hygiene and Tropical Medicine Ethics Committee (Ref: 16191) and the Institute for the Development of Human Research Protections (IHRP) Ethics Committee (approved 21-01-2018, no ref. number assigned). Appendix 3 contains copies of the two IRB letters of approval.

3.4 Reflexivity statement

As a social scientist, I know that my proclivities, as a thinker and researcher, had a role in constructing the knowledge presented in this thesis. My values, ontological world views, and epistemological leanings shaped the study design and outputs.

For example, my desire for migration to be safe and free for everyone ('free' as in liberty) motivated the thesis aim and research questions. As a complex-realist, I am persuaded that rigorous scientific research *can* identify 'real' causal mechanisms that exist in the 'knowable' world, but that this requires specific epistemological frameworks, methodologies, methods, and tools. Together, these personal motivations and academic convictions shaped this applied piece of research that aims to inform safer migration interventions.

Furthermore, my assumptions, informed by my experiences and knowledge of migration shaped how I chose to ask about migration processes in the interviews. For example, my own international migrations have all been 'regular' because of the privileges afforded to me as a middle-class, advanced educated, dual-citizen relocating between two high-income and stable states. However, even before beginning this research, I have assumed there is a degree of informed logic to why so many migrants, in very different almost incomparable circumstances to my own migrations, *choose* to migrate irregularly. My assumption, but increasingly my empirically informed hypothesis, is that despite the international community's adoption of "safe, orderly, and fair migration" as the aim that steers policy and practice, that regulated migration is more often to the benefit of the state than it is advantageous for the millions of low wage migrant workers. These assumptions and curiosities led me to pursue these 'grey areas' where there are complex, non-linear relationships between *how* migrants choose to migrate and their outcomes (i.e., more regularity does not always equate to more safety - why?). These questions about the complexity of migration

motivated my methodological choices and, in turn, I have been comfortable to wrestle with these complexities in what Davies calls the "tripartite relationship" between myself, the participants of this study, and their data (130). My aim was to stay neutral during this research and to communicate neutrality to the research team, but at every stage of the researcher-research relationship, I positioned myself, the subject, as a complex realist and the object, low wage migration, as a complex system.

In addition to complex realism, I adopted standpoint epistemology to contextualise and interpret the knowledge produced in this thesis. Standpoint epistemology contends that: 1) knowledge is socially situated; 2) marginalised people have some positional advantages in gaining some forms of knowledge; and 3) research ought to reflect these facts (131). Olúfémi O. Táíwò, philosopher and political scientist, writes that even as we increasingly 'defer' the mic to the voice of the oppressed community with certain positional advantages to some knowledge, such as low wage migrant workers with lived experiences of irregular migration, that we cannot ignore the fact that being in the position *to* defer reflects a degree of 'in the room' privilege (132). He goes on to say that "the problem emerges from how the rooms themselves are constructed and managed" and that we must be more accountable to those *not* in the room (132). Citing philosopher Sandra Harding, he explains that this sort of approach to knowledge construction, a *standpoint epistemology approach* demands more rigour from science, not less. I am in a very privileged and relatively small 'room' of academic researchers and practitioners conducting applied research on low-wage labour migration. I enjoy both personal and financial rewards for the work associated with that room. However, I am aware that it is a flawed space that is lacking the breadth of perspectives needed to understand complex low-wage labour migration systems and that it is a room of people that are often restricted in how they can speak or act by their respective institutional or disciplinary approaches. Thus, with the space I do have in this room, I have

chosen to ask the open-ended questions of a marginalised population, in the hope that their positional knowledge can be sufficiently represented to broaden the collective knowledge informing safe migration intervention.

This thesis is driven by activist motives, guided by complex realism, grounded in subject knowledge, but ultimately, as a researcher with undeniable 'being-in-the-room' privilege, my goal in data collection and analysis were to describe the complex system and causality as described by migrant workers' lived-experiences and entrusted to my interpretation.

Chapter 4. Results

The methodological contributions and empirical results of this thesis are presented across four interconnected research papers.

Section 4.1 – Paper 1 is a published systematic review that aimed to take stock of migration and 'modern slavery' ABMs, which later inform the ABM methods used in Paper 4.

Section 4.2 – Paper 2 is a methodological 'research note' that describes the rationale for and design of a novel mixed methods complex system study. This paper summarises the MMSNA study tools and corresponding lessons and reflections from using these tools. This paper also gives a brief introduction to how the MMSNA data and findings presented in Paper 3 were used to inform the ABM design in Paper 4.

Section 4.3 – Paper 3 presents the empirical findings on migration networks and pathways from the MMSNA study.

Section 4.4 – Paper 4 presents the empirically-based ABM that was guided by the conclusions of Paper 1 and informed by the findings in Paper 3.

This thesis is written in research paper style, which means each paper has been written in preparation to submit for peer review. The paper 'preambles' briefly describe the paper content and the intended journal for submission. Some of the overall study design and empirical aim will repeat across Papers 2-4 as they all draw on the same empirical study.

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RESEARCH PAPER COVER SHEET

SECTION A – Student Details

Student ID Number	388074	**Title**	Miss
First Name(s)	Alys Mary		
Surname Name	McAlpine		
Thesis Title	Mediated labour migration in the Myanmar-Thailand corridor and precarious outcomes: a mixed methods social network analysis and agent-based model		
Primary Supervisor	Cathy Zimmerman		

SECTION B – Paper already published

Where was the work published?	Journal of Computational Social Science		
When was the work published?	18 August 2020		
If the work was published prior to registration for your research degree, give a brief rationale for its inclusion	NA		
Have you retained the copyright for the work?*	Yes CC-BY license	Was the work subject to academic peer review?	Yes

SECTION C – Prepared for publication, but not yet published

Where is the work intended to be published?	
Please list the paper's authors in the intended authorship order:	
Stage of publication	Choose an item.

SECTION D – Multi-authored work

For multi-authored work, give full details of your role in the research included in the paper and in the preparation of the paper.	I led the review, drafted the search protocol, screened the articles (with LK), conducted the data extraction and analysis, and authored the first draft of this paper.

SECTION E

Student Signature	[redacted]
Date	27-06-2021

Supervisor Signature	[redacted]
Date	27-06-2021

4.1 Systematic Review

4.1.1 Preamble to Paper 1

The first paper in this thesis is a systematic review of ABMs simulating migration or 'modern slavery'. The aim of the review was to take stock of the purpose of these ABMs and to synthesise the development and analysis of these models to inform future applications of ABM methods in migration and modern slavery research.

Specifically for this thesis, the review served as a methodological guide for the development of an empirically-based ABM. The review helped to inform what types of data and analysis might be best suited to inform and validate the low wage labour migration ABM (Paper 4).

This systematic review has bee peer-reviewed and published in the *Journal for Computational Social Science*. Cited here:

McAlpine A, Kiss L, Zimmerman C, and Chalabi Z. Agent-based modelling for migration and modern slavery research: a systematic review. *Journal of Computational Social Science* (2021) 4:243-332. https://doi.org/10.1007/s42001-020-00076-7

4.1.2 Paper 1

Agent-based modelling for migration and modern slavery research: a systematic review

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Abstract

This systematic review aims to synthesise how agent-based modelling (ABM) has been used in migration and modern slavery research and provide the basis to model development for social science researchers exploring the use of ABM. We searched five bibliographic databases using two terminology categories: 1) migration or modern slavery terminology; 2) complex system methods terminology. Two reviewers conducted independent article screening. Peer-reviewed articles presenting original migration or modern slavery ABMs were included. Data extraction included model development steps and model characteristics. The dataset was synthesised and compared across studies. We identified 28 articles for inclusion. Many of the ABMs tested theories and about half were based on empirical data. Model development varied considerably, and reported methods were extremely opaque. Only five studies used a structured development framework. The most common model involved agents deciding whether and where to migrate and attempting migration. Climate change was a common exogenous scenario modelled. Most of the ABMs did not undergo any sensitivity analysis or validation. ABM has a greater capacity to account for heterogeneous and dynamic decision-making than more frequently applied methods in research on migration and modern slavery. However, there is still a paucity of studies adopting ABM methods. These reviewed ABMs highlight gaps in the reporting and implementing of model development. ABM is a promising technique to address many urgent and complex questions in research on migration and modern slavery to better support decision-makers, but addressing current methodological gaps is a critical first step.

Introduction

This review aims to explore how agent-based modelling (ABM), a complex systems science method, has been applied to research on migration or modern slavery, and to synthesise the ABM model development in this field of study to inform future applications of these methods. ABM, particularly in relation to socio-ecological systems modelling, has increasingly been employed to study many dynamic multi-scale research questions, such as ecosystem management, collective resource sharing and it is a particularly well-established method in studies of land use (133). Ecological complex systems modelling has paved the way for bridging many other disciplines, including social sciences, with complexity science. We believe that interdisciplinary ABM methods present an opportunity to address many critical, unanswered, and complex questions in migration and modern slavery research and at the nexus of these two research topics. In a first step to advance the adoption of these methods in this field of research, this review synthesises and assesses the use of ABM in migration and modern slavery research to date

This review builds on the work of modellers that have been using and reviewing the use of ABM to explore emergent trends in migration, particularly migration influenced by environmental changes, social networks and decision processes such as utility maximization (134–136). Bell, Hernandez and Oppenheimer pointed out that many of the ABMs in this field focus on singular push-factors (e.g. climate change) and usually only consider the pull-factors or destination choices *after* the agents have surpassed a push-factor threshold (135). Klabunde and Willekens explored the decision-model choices for migration ABMs that span several dimensions (forming expectations, evaluating options, the complexity of the decision, networks influencing decisions, etc.) and it is clear that not all of these dimensions are critically addressed or at least not articulated in current migration ABMs (134). Many ABM modellers have asserted that

without clear documentation of the full spectrum of model development (or 'modelling cycles', including final model validation), that there are limitations to the contributions ABMs can claim or methodological advancements they can foster (133, 137). In this vein, our aim is to contribute a systematic review of the model development of migration ABMs to allow for more informed dialogue on the gaps in model development and reporting of model development.

Why explore ABM for research on migration and modern slavery?

Many academics and practitioners are trying to understand the complexities of human migration to inform policy and practice, particularly to promote safer labour migration and address issues of modern slavery. For example, the United Nations' Sustainable Development Goals include taking "immediate and effective measures to eradicate forced labour, end modern slavery and human trafficking" (Goal 8.7) and to "facilitate orderly, safe, regular and responsible migration and mobility of people" (Goal 10.7) (9). There is a growing body of research focusing on the causal pathways between low-wage labour migration and forms of labour exploitation, also known as modern slavery (7, 138). Yet, there is limited evidence to explain the nexus between low-wage labour migration and modern slavery completely (14), including evidence gaps on the complex mechanisms that contribute to entry into slavery-like conditions versus decent work (4, 7, 15). That is, we have yet to understand the pathways that lead to different migration-related outcomes, in addition to understanding the drivers of migration as some of the previous ABM migration models have explored.

As an example, in public health, the disciplinary background of some of this reviews' authors, we have become increasingly aware that while the conventional epidemiological approaches can be useful to capture the effect of exposures on singular outcomes or offer estimates at the aggregate population-level data, they are often not suited to investigate the complex non-linear causal pathways that affect health (e.g. complex health behaviour

problems) (139). For example, epidemiological methods can describe well the aggregate experiences of migrant exploitation and health outcomes, such as the health outcomes of human trafficking (51), but they do not capture the complex system dynamics of labour migration and modern slavery. ABM has recently been recognised by the public health research community as a complex systems approach that can explore causal complexities inherent to human behaviour and population health (140–142)

This paper gives a brief introduction to ABM of social systems and describes current applications of these methods for exploring complex systems in migration and modern slavery research. Finally, this paper presents findings to contribute methodological learning that is transferable across many social and health science disciplines.

Agent-based modelling for complex social systems

Agent-based modelling is a method for studying complex systems. A complex system contains many parts interacting at the individual (micro) level in an irregular way and generally producing nonlinear outcomes with regularity at the systems, population or aggregate (macro) level (143–145). Stephen Wolfram, one of the founding scholars on complex systems theory, said, “It is now a crucial problem for many areas of science to elucidate the mathematical mechanisms by which large numbers of such simple components, acting together, can produce behaviour of the great complexity observed” (146). ABM is a computational simulation technique that has gained increasing popularity in recent decades across many social science disciplines to study social complexity in human systems (145). For example, public health and health systems research has employed ABM methods to study communicable and noncommunicable diseases, health behaviours, and other topics in social epidemiology (147). These methods are increasingly recommended to evaluate complex health systems and prevention interventions (141, 148).

In simple terms, an ABM consists of a simulated population of autonomous, goal-oriented individuals (agents) that can interact with each other (agent-to-agent) or with their simulated environment (agent-to-environment). Agents can be assigned specific attributes (demographics, attitudes, risk aversion, etc.) that in combination with the rules of the model (how individuals behave, make decisions, interact with their surrounding environment, etc.) govern the steps that result in the dynamic and emergent outcomes (149).

Experts from both computer science and social science have written extensively on the unique capabilities and usefulness of ABMs in social science research (143, 145, 150, 151). In short, ABMs have a bottom-up approach that enables exploration of individual-level behaviours and causal mechanisms that lead to macro-level aggregate emergent phenomena, which can only be inferred from modelling the individual-level interactions. The task is to replicate a population, the environment and its patterns in such a way that the model produces similar emergent properties or outcomes to the observed outcomes in the real world (152). Some scholars in this methodological field argue that the next frontier of explanatory social science research is being able to 'grow' the phenomenon of interest from micro-level rules (143). For example, recent ABM research on health-pertinent behaviours such as smoking, diet and interpersonal violence, have successfully simulated groups of individuals that move in a social or physical space, exchange information, model behaviour, copy behaviour and make decisions (147, 153). All these individual actions in aggregate replicate real world trends in health behaviours and outcomes- such as smoking habits or obesity amongst close links in social networks.

An example of a complex dynamic system in migration research: Low-wage labour migration and exploitation

Globally, the majority of migrants participate in the labour force (15). The majority of victims of modern slavery are low- or no-wage labourers and a significant proportion are migrant workers (4). These two global phenomena, low-wage labour migration and modern slavery, are linked in complex and dynamic ways. Figure 10 is a conceptual framework visualisation depicting some of this complexity. In Figure 10, we present the migrant on a pathway between origin and destination and, in some cases, a pathway that returns to origin. Individuals very rarely migrate without the help of social or intermediary networks, such as migrant networks at destination or labour recruitment networks (60). Thus, we have also presented the migrant connected to a dynamic network of possible relations that evolves throughout the migration cycle. These migration-facilitation networks and any associated social or migratory norms are also influenced by exogenous entities, such as climate change, economic development and labour recruitment (5). An individual experience of migration is influenced by all these factors (for example, individual behaviours, social networks, social norms, immigration governance or labour markets). Not included in Figure 10 are the range of outcomes at every stage in the migration cycle on individual- and population levels that operate through feedback mechanisms which, over time, cause emergence of population level migration behaviour which can only be inferred from individual level interactions.

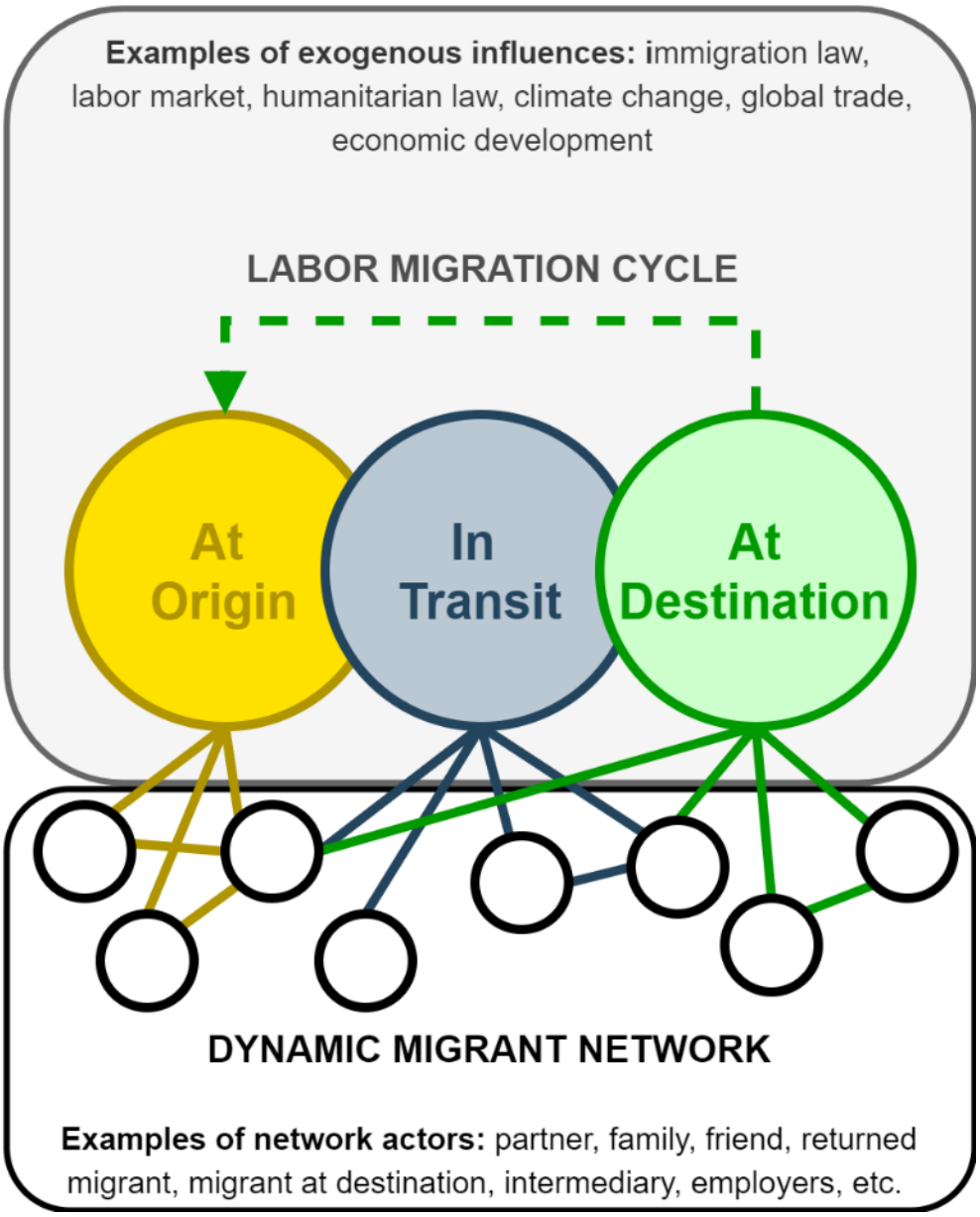

Figure 10. Dynamic migrant social networks

Theoretical developments in the fields of migration research and public health research draw attention to the multi-causal, dynamic, multi-directional and nonlinear nature of complex social problems, the ecological systems approach to addressing social phenomena, and the importance of concepts of social networks, decision making under uncertainty and bounded rationality (14, 134, 142, 153–155). There is a convincing argument for adopting new methods of data collection and analysis that reflect these

theoretical concepts. Agent-based modelling enables complex dynamic simulations that encompass multiple ecological levels (individuals, households, social networks, migration corridors, exogenous forces) and incorporates heterogeneous individuals (Figure 10).

Donors, practitioners and policymakers advocating for the protection and wellbeing of low-wage labour migrant workers rely on research to provide evidence on the challenges these individuals face during their migration and employment, to inform effective interventions. To date, most of this research has been conducted using conventional statistical or qualitative research methods. The statistical methods implicitly treat labour migration as a one-dimensional, one-directional, linear and static 'exposure-response' type relationship between drivers of migration and migration outcomes. Such methods do not take into consideration the complexity of labour migration or its dynamic nature. These analyses do not account for the various feedback mechanisms governing the interaction of different actors with other actors and with their environment, the time-delays between a stimulus (action) and the corresponding response, and the nonlinear nature of responses to stimuli. The current body of evidence primarily tries to offer insights on the drivers of migration, the demographics of migration, migration corridors and outcomes, including growing evidence on the range of harmful outcomes such as unfair recruitment, labour exploitation and forms of modern slavery. But these analyses do not improve our knowledge on labour migration, or the nature of the complex exposures and mechanisms related to migration. Every story of migration encompasses information seeking, decision making, interactions and exchanges with individuals, groups and systems.

Examples of other ABM reviews

As referenced earlier, to our knowledge, there are three reviews of migration ABMs relevant to the aim of this review, including Klabunde and Willeken's review focusing on decision-model choice including integration of social networks (n=22 included publications) (134), Thober and colleagues review of ABMs of environmental-migration linkages (n=21) (136), and Bell and colleagues brief background review on ABMs exploring migration push-pull factors to present their migration ABM framework (non-systematic, n= ~8) (135). Other examples of ABM reviews include previous reviews on the use of ABM to study other social or health science topics, such as urban crime (n=45) (156), non-communicable diseases (NCDs) (n=22) (157), obesity (n=38) (158), public health (non-systematic, n= ~45) (147), and health systems (n=11) (159). These reviews reported notable increased interest in and application of ABM methods in their respective field of study, despite still small yields compared to other reviews including different methods. The reviews focused on urban crime, NCDs, obesity, and public health all discussed the current gaps in standardised ABM methods and a lack of transparency in model development as a major limitation in the field for model replication and systematic comparison. Cassidy et. al.'s review on the use of ABM and System Dynamics (SD) models in healthcare systems research did not conduct extensive extraction on model development processes, and so did not address these issues, but did conclude that the topics of data source choices is a critical next area of review in complex healthcare systems modelling (159). The most relevant of all these reviews to the present one is Klabunde and Willekens's review of ABMs of migration, which differs from this review as it focused primarily on the behavioural theories that informed the decision-making models (134). The present review draws on this previous work and proposes a wider scope of investigation. The key contribution of this review is to incorporate a broader set of search terms to include modern slavery phenomena as well as migration. Furthermore, this review extracted data points on the full

spectrum of the ABM development process, not just the decision-making element. We will reference Klabunde and Willekens's review throughout the methods and discussion sections of this paper, particularly because of the strength of that review's synthesis and analysis of the decision-making process, which was not within the scope of this review, but an important topic for ABM development.

Review aim. This review aims to describe how ABM has been used in research on migration and/or forms of modern slavery. Findings are intended to inform future studies on the application of this methodological approach, including guidance on model calibration, model development, sensitivity analysis and model validation. This review aims to contribute a summary and assessment of the state of the art of ABM use in migration and modern slavery studies to encourage and inform future adoption of ABM methods in this field.

Methods

This review adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) statement (124). The full protocol for this review, including comprehensive database search scripts, can be shared upon request to the corresponding author. A condensed version of the search protocol can be found in the Supplementary Materials (SM-1). The summary of the methodology is outlined here.

The search was conducted on 5 bibliographic databases covering public health, social science, and computer science disciplines (Table 5).

Table 5. Bibliographic database searches

Databases	Date of search	Filters applied
Web of Science, Scopus, PubMed	09/06/2019	**Document Type:** Articles; Reviews **Years:** 1999-2019
MathSci, arXiv	18/09/2019	

The search strategy included two subject areas: 1) migration or modern slavery; and 2) dynamic systems modelling or network analysis methods (Figure 11 and Table 6). The full search scripts are included in Appendix 4.1.

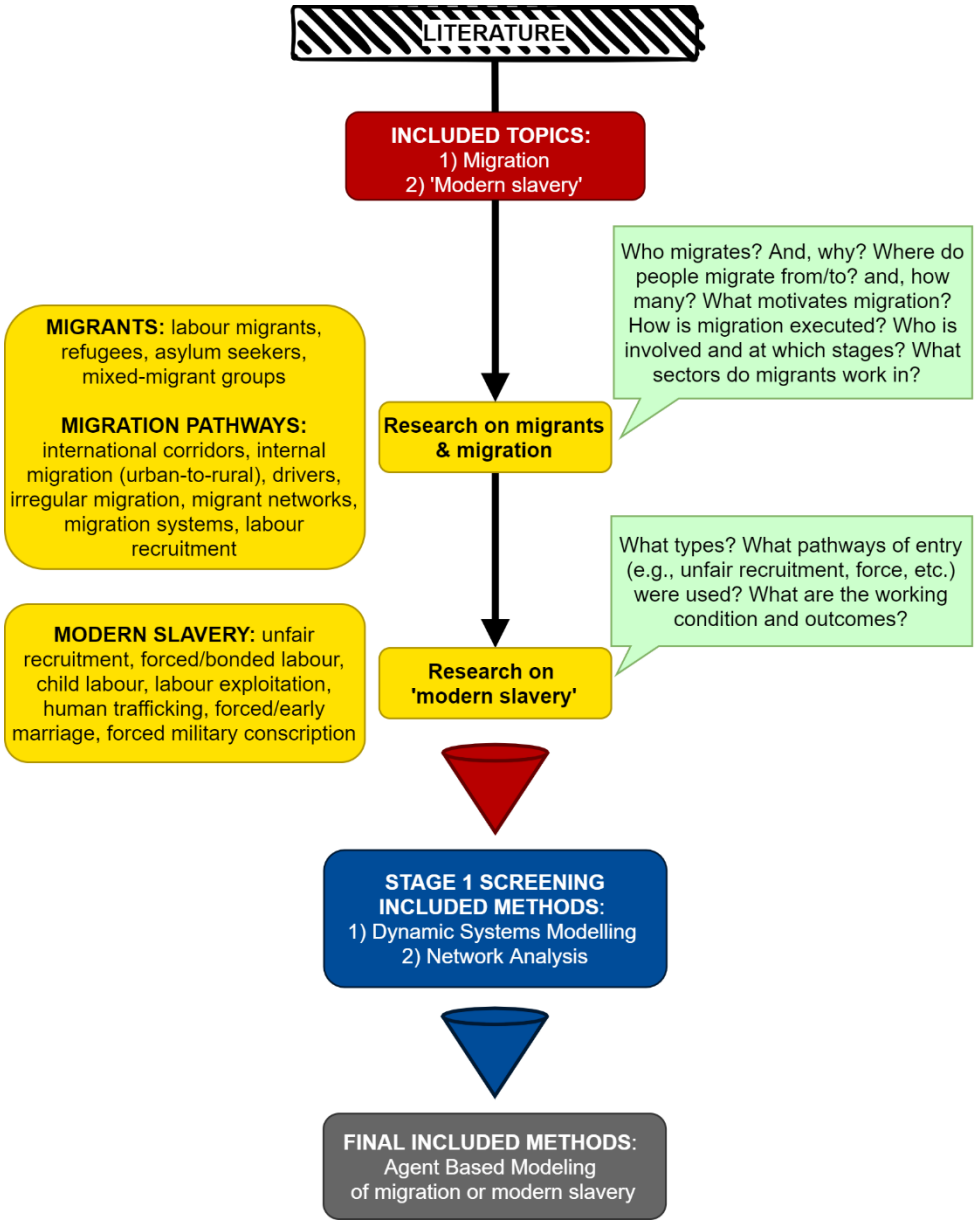

Figure 11. Systematic review subject areas

Table 6. Summary of the two-concept search strategy with 'not' search terms

Concept 1: migration; low-wage or hazardous labour; labour recruitment; modern slavery or human smuggling	Concept 2: complex system simulations; network analysis
1: MIGRATION migrat* OR migrant* OR immigrat* OR immigrant* emigrat* OR emigrant*OR refugee* OR assylum OR "internal* displace*" OR (displace* NEAR/4 people*) OR (displace* NEAR/4 population*) humanitarian 2: LOW-WAGE OR HAZARDOUS LABOUR "low-wage" OR "low-skill" OR (occupation* NEAR/4 (health OR safety)) OR "trade union*" 3: labour RECRUITMENT labo$r recruit* OR labo$r broker* OR lab$or agent OR labo$r intermediar* OR "labo$r market*" OR "labo$r supply" 4: MODERN SLAVERY (human NEAR/4 traffick*) OR (human NEAR/4 smuggl*) OR (migrant* NEAR/4 traffick*) OR (migrant* NEAR/4 smuggl*) OR (refugee NEAR/4 traffick*) OR (refugee NEAR/4 smuggl*) OR "modern slave*" OR "forced labo$r*" OR "forced work*" OR "child labo$r*" OR "child work*" OR (child NEAR/4 traffick*) OR "bonded labo$r*" OR "bonded work*" OR "debt bond*" OR "unfree labo$r" OR "labo$r NEAR/4 (exploit* OR abus*)" OR "early marriage*" OR "child marriage*" OR "child bride*" OR "forced marriage*" OR "forced bride*" OR (bride NEAR/4 traffick*) OR "forced conscription" OR "child soldier*" OR "rebel wives"	**1: DYNAMIC SYSTEM MODELILNG** "agent-based model*" OR "individual-based model*" OR "stochastic-dynamic model*" OR "computational agent*" OR "cellular-automata*" OR "social simulat*" OR microsimulat* OR ("machine learning" NEAR/4 "dynamic system*") OR (system* NEAR/4 "interact* object*") OR "system dynamics" OR "complex system* simulation" OR "complex system* model*" "discrete-event simulation" OR "discrete-time Markov chains" **2: NETWORK ANALYSIS** "network analysis" OR "network data" OR "network model*" OR "bayesian network"
NOT :(cancer* OR tumo$r* OR protein* OR gene OR genetic OR genomic* OR oncolog* OR immunolog* OR "earth-system* model*" OR "oceanic-migration*" OR "bird NEAR/4 migrat*" OR "fish-migration" OR species OR "cell-migrat*" OR breed* OR molecul* OR bacteria* OR particle* OR "cell-cell" OR tissue OR larva* OR ecosystem* OR egg* OR predator* OR sedement*)	

Eligibility criteria

The search only included peer-reviewed articles published between 1 January 1999 and the date of search. Additionally, the full article had to be available in English. We did not apply any exclusion criteria based on the discipline, data sources (quantitative, qualitative, secondary, theoretical, etc.), study type (cross-sectional, longitudinal, trial, etc.), quality of the study, or the publishing journal. The studies needed to meet two criteria pertaining to 1) the study topic and 2) the study methodology.

1) Study Topic: The research questions and outcomes of the study addressed one or more of the following themes: migration flows; drivers of migration; demographics of migrant populations; migrant social networks during migration planning, implementation or job-seeking; migrant labour; immigration policy; labour recruitment; safer labour migration interventions or migrant worker health interventions; remittance flow; return migration; modern slavery or child labour (including child soldiers).

The search protocol outlined similar topics that would *not* be included: disease spread through migration; general migrant population health at destination (unless specific to migrant workers or forms of modern slavery); humanitarian coordination or service delivery broadly; disaster preparedness or short term emergency evacuation; residential or local migration (for example, urban sprawl, residential neighbourhood choice, etc.); ethnic diversity at destination (without exploring migration mechanisms or networks that facilitated migration); immigrant cultural integration at destination (except where relevant to employment or earnings as described above); animal migration; tourism; or broad low-wage or hazardous occupation research without disaggregation by migrant status.

2) Study Methodology: The search had two-stage inclusion criteria. The first stage included a broader range of computational and network methodologies that could provide more comprehensive findings on the types of innovative methodologies being used in migration studies. This stage also was designed to prepare for a paucity of literature on ABMs to review in this subject area. The second stage inclusion criteria, which was applied to the articles that were eventually fully extracted for this review, included only original research that used agent-based modelling. The results described in this paper are based on the articles identified using the second-stage criteria.

Study selection

The full database yields were uploaded to the Rayyan systematic review software and de-duplicated (160). Two co-authors (AM, LK) completed independent-blind abstract reviews for the 1,707 articles. The reviewers met to discuss a collection of 100 articles that received conflicting decisions. The reviewers were able to agree on a final inclusion decision for all 100 articles through referral to the study protocol and without input from a third reviewer. In total, the first round of abstract-screening included 137 articles. A second round of abstract-screening narrowed the yield to agent-based modelling papers. At the final stage, 58 articles were full-text screened and 28 articles met the final inclusion criteria (Figure 12).

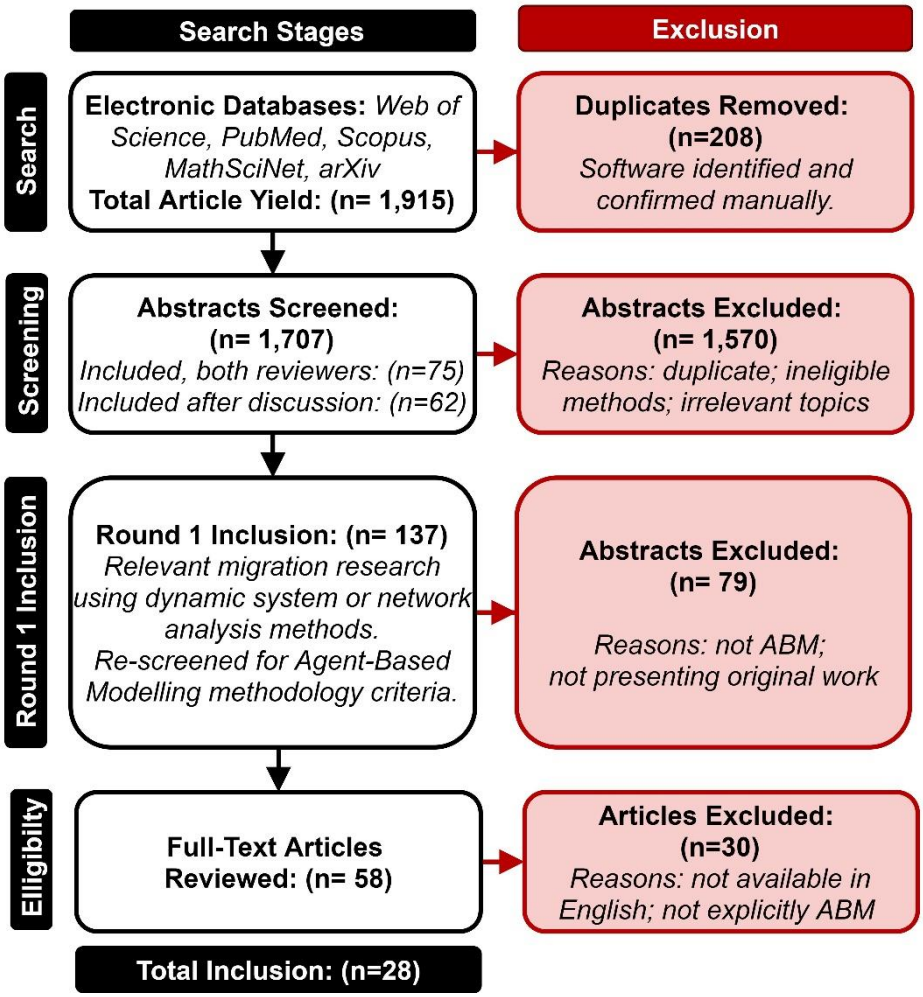

Figure 12. PRISMA systematic review flowchart

Data extraction

This is a review of the *methodology* of these studies, not a synthesis of findings. Therefore, the data extraction process captured the authors' affiliations and study aim, model inputs, model development, model process and the analysis and validation methods completed by the authors. This method is similar to systematic reviews of ABMs on other social or health science research topics that focused on the study design, model specifications (agents, environment, decision rules), and model analysis (sensitivity analysis, model validation) for data extraction and synthesis (157, 158, 161–164). The data extraction tool was informed by the guiding questions outlined in the Overview, Design Concepts and Details + Decision Making (ODD+D) protocol for ABM development, which is an adaptation of the original Overview, Design Concepts and Details (ODD) protocol developed to standardise descriptions of individual-based models (IBMs) and ABMs (137, 165, 166). Before the development of the ODD framework in 2006, computer simulation models, such as ABMs, did not have standardised guidelines for dissemination (165). Therefore, without these protocols, IBMs and ABMs were reported with varying levels of detail and often in insufficient detail to understand all the modelling choices. The ODD framework elicits critical descriptions of the model design and development and the ODD+D protocol added detailed guidance on how to report the decision-making elements in the development framework, which was particularly important for ABMs. We believe that the ODD+D framework offers a valuable approach to extracting and understanding model development and model comparison across studies and encouraging wider use of this framework by other ABM modellers, particularly in the social sciences. The lead author for this review extracted the data points from all 28 articles using comma-separated values (CSV) files according to key questions in the ODD+D protocol. The extraction table was quality checked by all three co-authors in both work-shop style review sessions and independent reviews.

Data synthesis

Since most of the data points extracted for this review were descriptive characteristics of the ABMs, the data extraction table is largely qualitative and too large to present in article format. In this same respect, the challenges to qualitative data synthesis in systematic reviews also applies to this methodological review (167). When possible, we have categorised certain data extraction points to more easily summarise or draw conclusions on the range of methodological choices made by the authors. Therefore, we have grouped most of the data extraction into seven results tables (Table 8-14) and presented our data synthesis for each table. See Table 7 for summary of results tables. The synthesis includes categorizing and summarizing the key data extraction points to make comparisons and highlight gaps across all 28 ABMs. The full data extraction table can be found in the Supplementary Materials (SM-3). We did not assess the quality and suitability of ABM methods used in the included studies because it is outside the scope of the review. This is in part because, to our knowledge, there is not currently a standardised instrument to assess the quality of ABM models like the tools that exist for assessing other research methods, such as The Critical Appraisal Skills Program (CASP) tool (168).

Table 7. Results synthesised by sub-topic and presented in individual tables

ALL TABLES	Lead Author (Year)
TABLE 8: Included articles	Author(s)
	Year
	Title
TABLE 9: Study characteristics	Authors' institutional affiliation(s) (country)
	Authors' department(s)
	Journal
	Study purpose as summarised by reviewers (aim sub-category classification)
TABLE 10: Model Inputs	Decision model
	General concepts or theoretical basis for model design
	Data type
	Data source
TABLE 11: Model development	Time-steps and time-horizon
	Spatial characteristics
	Agent types: Agent attributes [micro characteristics]
	Exogenous or environmental characteristics [macro characteristics]
	Social networks [meso characteristics]
TABLE 12: Model process	Initialisation
	Model steps and decision rules
	Agent types: Agent actions
	Simulation scenarios
	Deterministic or stochastic (if stochastic: which model component)
TABLE 13: Model analysis and validation	Output variables
	Uncertainty and sensitivity analysis as described by the author(s)
	Model validation as described by the author(s)
TABLE 14: Model summary	Summary of model aim and model development

Results

In total, we identified 137 articles on relevant migration or modern slavery research topics that applied either network analysis or dynamic simulation methods. This included research using social network analysis, Bayesian network analysis, system dynamics modelling and various microsimulation methods. We then further excluded any article that did not use ABM methods. We identified 28 articles, included in this review, that explicitly detailed ABM (or 'Agent Based Simulation') in the methods (Table 8).

Table 8. Included articles

Author(s)	Year	Title
Alghais N, Pullar D, Charles-Edward E (169)	2018	Accounting for peoples' preferences in establishing new cities: A spatial model of population migration in Kuwait
Anderson J, Chaturvedi A, Cibulskis M (170)	2007	Simulation tools for developing policies for complex systems: Modelling the health and safety of refugee communities
Cai N, Ma HY, Khan MJ (171)	2015	Agent-based model for rural-urban migration: a dynamic consideration
Chesney T, Evans K, Gold S, Trautrims A (172)	2019	Understanding labour exploitation in the Spanish agricultural sector using an agent-based approach
Entwisle B, Williams N, Verdery A, Rindfuss R, Walsh S, et. al. (173)	2016	Climate shocks and migration: an agent-based modelling approach
Espindola AL, Silveira JJ, Penna TJP (174)	2006	A Harris-Todaro agent-based model to rural-urban migration
Fu Z, Hao L (175)	2018	Agent-based modelling of China's rural-urban migration and social network structure
Garcia- Diaz C, Moreno-Monroy A (176)	2012	Social influence, agent heterogeneity and the emergence of the urban informal sector
Hailegiorgis A, Crooks A, Cioffi-Revilla C (177)	2018	An agent-based model of rural households' adaptation to climate change
Hassani- Mahmooei B, Parris BW (178)	2012	Climate change and internal migration patterns in Bangladesh: An agent-based model
Henry A, Christensen A, Hofmann R, Steimanis I, Vollan B (179)	2017	Influence of sea level rise on discounting, resource use and migration in small-island communities: An agent-based modelling approach
Ichinose G, Saito M, Sayama H, Wilson DS (180)	2013	Adaptive long-range migration promotes cooperation under tempting conditions
Janssen MA (181)	2010	Population aggregation in ancient arid environments
Kniventon D, Smith C,	2011	Agent-based model simulations of future changes in

Wood S (182)		migration flows for Burkina Faso
Kniventon D, Smith C, Black R (183)	2012	Emerging migration flows in a changing climate in dryland Africa
Mena C, Walsh S, Frizzelle B, Xiaozheng Y, Malanson G (184)	2011	Land use change on household farms in the Ecuadorian Amazon: Design and implementation of an agent-based model
Naivinit W, Le Page C, Trebuil G, Gajaseni N (185)	2010	Participatory agent-based modelling and simulation of rice production and labour migrations in Northeast Thailand
Naqvi A, Rehm M (186)	2014	A multi-agent model of a low-income economy: simulating the distributional effects of natural disasters
Naqvi A (187)	2017	Deep Impact: Geo-Simulations as a Policy Toolkit for Natural Disasters
Raczynski S (188)	2018	Influence of the gregarious instinct and individuals' behaviour patterns on macro migrations: Simulation experiments
Silveira JJ, Espindola AL, Penna TJP (189)	2006	Agent-based model to rural-urban migration analysis
Simon M (190)	2019	Path Dependency and Adaptation: The Effects of Policy on Migration Systems
Smith C (191)	2014	Modelling migration futures: Development and testing of the Rainfalls Agent-Based Migration Model - Tanzania
Suleimenova D, Bell D, Groen D (192)	2017	A generalized simulation development approach for predicting refugee destinations
Tabata M, Eshima N (1 of 2)[1] (193)	2003	A self-referential agent-based model that consists of a large number of agents moving stochastically in a discrete bounded domain
Tabata M, Eshima N (2 of 2)[1] (194)	2004	The behaviour of stochastic agent-based models when the number of agents and the time variable tend to infinity
Walsh S, Malanson GP, Entwisle B, Rindfuss RR, Mucha PJ (195)	2013	Design of an agent-based model to examine population-environment interactions in Nang Rong District, Thailand
Wu J, Mohamed R, Wang Z (196)	2011	Agent-based simulation of the spatial evolution of the historical population in China
[1]Due to significant similarities between Tabata's 2013 and 2014 model presentations, these articles have been extracted together in one row of the data extraction table (Tables 8-14) (193, 194).		

This results section presents: the data extraction and synthesis of the study characteristics (Table 9); model inputs (Table 10); model development (Table 11); and model process (Table 12); model analysis (Table 13); and the summary of the model aim in relation to specific model development characteristics from Tables 8-13 (Table 14). But first, we will present two

important observations made during the screening and extraction process that are relevant to inferences about methodological procedures in ABM, one of the key objectives of this review: *1) Agent-based models are sometimes called by different names; 2) Few studies reported using ODD+D or an alternative development framework.*

1) Agent-based models are sometimes called by different names

Similar to findings from Klabunde's review, it was challenging to ascertain whether some dynamic simulation models (e.g. spatial or dynamic microsimulations, individual-based models) that were not explicitly called ABM (or ABS) did in fact include sufficient agent-interaction or decision-based behavioural modelling to be included as ABMs (134). This challenging grey area of inclusion is not altogether surprising, since expert commentaries on the origins of ABM explain that cellular automata, microsimulations, and agent-based approaches have been developed and improved on in parallel, across disciplines, with different aims, and different names, but seemingly similar function and capabilities (197, 198). For example, microsimulations are often considered to be the method of choice when exploring policy impacts and ABM are used more commonly for theory testing. Distinctions aside, these models all have bottom-up approaches that model individual behaviours, often heterogeneous (198). While at times the distinction appears arbitrary, for this systematic review we decided to apply strict criteria that the paper had to identify the methods as ABM to be included in the extracted yield of articles. In part, this is to ensure the reproducibility of the review, but also to allow for as uniform and complete data extraction of methodological processes as possible, which we determined would be more feasible if the authors were writing their methods from an ABM framework. We have included a table in the Supplementary Materials (SM-2) with a list of the 8 articles we determined were implicitly describing ABM but were excluded for the reason just described.

2) Few studies reported using a development protocol

Although the majority (n=24) of the included articles were published after the introduction of the well-known 2006 ODD framework for simulation or the 2013 ODD+D framework for ABMs (see Table 8 for publication years), very few of the articles described using any framework in developing or reporting the ABM. Only one study used the ODD+D framework designed specifically with ABMs in mind (177), 3 studies used the ODD framework (169, 178, 185) and one used a framework developed by the authors themselves which they called a generalised Simulation Development Approach (SDA) (192). This review, as noted, used the ODD+D framework to inform the data extraction tool, in part because we hoped a majority of recent ABM research would have used this framework. It appears the uptake of this framework tool is still slow, and this continues to create challenges for understanding model inputs, development and analysis as well as comparison across studies. We note this before addressing the bulk of the synthesis of the study methods to inform the reader that the extraction process had to adapt to a wide range of styles in disseminating the model development process. Below are the main results of this review according to the six sections described above.

1. Study characteristics

Between 1999-2019, the review's included publishing years, there have been a steadily increasing number of studies using agent-based modelling to for migration and modern slavery research (Figure 13).

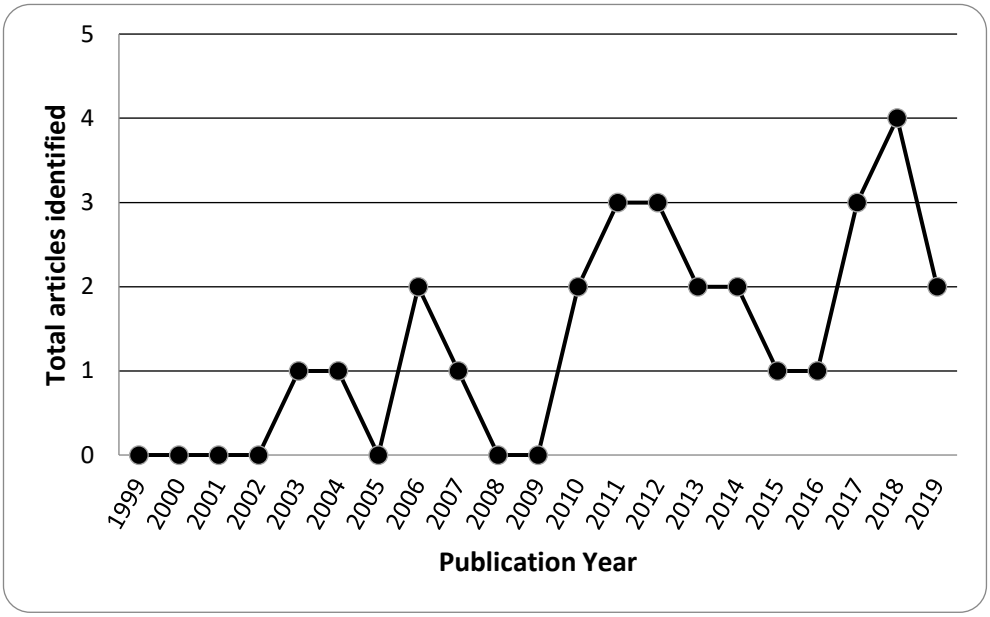

Figure 13. Included articles by year of publication

The authorship characteristics, both by institutional affiliation and by disciplinary associations, represented a diverse range of home institutions, country of institutions and disciplinary departments or research centers (Table 9). Nine of the included studies were authored by multi-country authorship teams and thirteen of the included articles indicated cross-disciplinary authorship teams. It is also noteworthy that ten of those cross-disciplinary authorship teams consist of both 'hard sciences' (mathematics, engineering, physics, etc.) and 'soft sciences' (sociology, anthropology, economics, demography, etc.). For example, the Walsh et. al. article was authored by scholars from backgrounds in Mathematics, Information Science, Spatial Analysis, Geography, Demography, Sociology, and International Studies, who could each bring his or her disciplinary expertise to the task of mathematically modelling environmentally influenced migration patterns (195).

Table 9. Study characteristics

First Author (Year)	Author Institutional Affiliations (Country)	Author Department Disciplines	Journal	Study Purpose (summarised)	Broad research category
Alghais (2018) (169)	The University of Queensland (Australia)	Environmental Science	Plos One	To explore segregation levels, internal migration and residence preferences in Kuwait urban areas.	Migration demographic or regional
Anderson (2007) (170)	Purdue University (USA)	Sociology, Anthropology	Health care management science	To understand the collective behaviours of refugees and internally displaced persons.	Humanitarian migration
Cai (2015) (171)	Northwest University for Nationalities (China), National University of Sciences and Technology (Pakistan)	Engineering, Economics	Physica A: Statistical Mechanics and its Applications	To simulate rural-urban migration.	Migration demographic or regional
Chesney (2019) (172)	Nottingham University (UK), University of Kassel (Germany)	Business, Economics	Journal of Cleaner Production	To explore the diffusion of slavery and anti-slavery practices in the agricultural industry.	Slavery
Entwisle (2016) (173)	University of North Carolina at Chapel Hill (USA), University of Washington (USA), East-West Center (USA), University of Iowa (USA), Center for Geographic Information Science (USA), Mahidol University (Thailand)	Demography, International Studies, Sociology, Geography, Mathematics,	Population and Environment	To examine how climate shocks affect migration in rural agricultural areas of Thailand.	Environmental motivations for migration
Espındola (2006) (174)	Universidade Federal Fluminense (Brazil), Universidade Estadual Paulista (Brazil)	Physics, Economics	Brazilian Journal of Physics	To explore crucial assumptions of an economic utility maximisation migration model.	Migration theory testing
Fu (2018) (175)	Johns Hopkins University (USA)	Civil Engineering, Sociology	Physica A: Statistical Mechanics and its Applications	To understand the co-evolution of social networks and China's rural-urban migration patterns.	Social impacts on migration

First Author (Year)	Author Institutional Affiliations (Country)	Author Department Disciplines	Journal	Study Purpose (summarised)	Broad research category
Garcia- Diaz (2012) (176)	University of Antwerp (Belgium), Universidad de los Andes (Colombia), University of Groningen (The Netherlands)	Management, Industrial Engineering, Economics	Physica A: Statistical Mechanics and its Applications	To explore the informal labour sector and social influences in urban-rural migration.	Social impacts on migration
Hailegiorgis (2018) (177)	George Mason University (USA)	Social Complexity	Journal of Artificial Societies and Social Simulation	To explore the adaptive capacity of Ethiopian rural households with respect to climate and land-use variations.	Environmental motivations for migration
Hassani-Mahmooei (2012) (178)	Monash University (Australia)	Econometrics	Environment and Development Economics	To study the population migration dynamics in Bangladesh due to extreme environmental shocks.	Environmental motivations for migration
Henry (2017) (179)	University of Arizona (USA), University of Copenhagen (Denmark), Ludwigs-Maximilians-Universität München (Germany), Philipps-Universität Marburg (Germany)	Public Policy, Geosciences, Economics	Environmental Conservation	To illustrate the importance of resource payoffs on individuals' migration in Pacific and Caribbean islands.	Economic utility of migration
Ichinose (2013) (180)	Anan National College of Technology (Japan), State University of New York (USA)	Complex Systems, Biology, Anthropology	Scientific Reports	To study the interaction between co-evolutionary cooperation and migration.	Social impacts on migration
Janssen (2010) (181)	Arizona State University (USA)	Human Evolution and Social Change	Ecology and Society	To explore the resilience, decision making and movement of the population in response to climate variability and resource degradation.	Environmental motivations for migration
Kniventon (2011) (182)	University of Sussex (UK)	Geography, Informatics	Global Environmental Change- Human and Policy Dimensions	To investigate the role of the environment in Burkina Faso in individuals'' decision to migrate.	Environmental motivations for migration
Kniventon (2012) (183)	University of Sussex (UK)	Geography	Nature Climate Change	To explore how climate and demographic changes influence migration within and to Burkina Faso.	Environmental motivations for migration

First Author (Year)	Author Institutional Affiliations (Country)	Author Department Disciplines	Journal	Study Purpose (summarised)	Broad research category
Mena (2011) (184)	Universidad San Francisco de Quito (Ecuador), University of North Carolina at Chapel Hill (USA), University of Iowa (USA)	Environmental Sciences, Geography, Demography	Applied Geography	To assess the drivers of land-use change and migration as an adaptive response in the Ecuadorian Amazon.	Environmental motivations for migration
Naivinit (2010) (185)	Chulalongkorn University (Thailand), Université Paris Ouest Nanterre-La Défense (France), Ubon Rajathanee University (Thailand)	Unspecified, Biology	Environmental Modelling & Software	To build a representation of rainfed lowland rice farming, water availability, and labour migration in Thailand.	Environmental motivations for migration
Naqvi (2014) (186)	Vienna University of Economics and Business (Austria), Chamber of Labor (Austria)	Economics, Labour	Journal of Economic Interaction and Coordination	To capture adjustments and spatial spill over effects following disaster-like negative shocks in Pakistan.	Humanitarian migration
Naqvi (2017) (187)	International Institute for Applied Systems Analysis (Austria), Vienna University of Economics and Business (Austria)	Applied Systems Analysis, Ecological Economics	World Development	To create a geo-simulation that replicates natural disaster outcomes to identify vulnerability hotspots for relief delivery.	Humanitarian migration
Raczynski (2018) (188)	Universidad Panamericana (México)	Engineering	Journal of Human Behaviour in the Social Environment	To simulate the migrations of social groups influenced by the gregarious effect and individual behaviour patterns.	Social impacts on migration
Silveira (2006) (189)	Universidade Estadual Paulista (Brazil), Universidade Federal Fluminense (Brazil)	Economics, Physics	Physica A: Statistical Mechanics and its Applications	To examine rural-urban migration during the industrialization process.	Migration demographic or regional
Simon (2019) (190)	University College London (UK)	Political Science	Journal of Artificial Societies and Social Simulation	To demonstrate how migrants adapt to policy change by showing the effect of return migration flows.	Migration demographic or regional

First Author (Year)	Author Institutional Affiliations (Country)	Author Department Disciplines	Journal	Study Purpose (summarised)	Broad research category
Smith (2014) (191)	University of Sussex (UK)	Geography	Climate and Development	To explore the role of rainfall in shaping the drivers of migration within the Tanzanian communities surveyed.	Environmental motivations for migration
Suleimenova (2017) (192)	Brunel University London (UK), University College London (UK)	Computer Science	Scientific Reports	To predict the distribution of refugees across camps in three African conflicts to inform governments and organisations responding in humanitarian crises.	Humanitarian migration
Tabata (2003) & (2004)* (193, 194)	Kobe University (Kobe, Japan), Oita Medical University (Oita, Japan)	Applied Mathematics, Statistics	Applied Mathematics and Computation	To describe interregional migration theory.	Migration theory testing
Walsh (2013) (195)	University of North Carolina at Chapel Hill (USA), University of Iowa (USA), Central Michigan University (USA), University of Washington (USA)	Geography, Demography, Sociology, Mathematics, Information Science, Spatial Analysis, International Studies	Applied Geography	To examine land use change in agricultural Thailand and migration as an adaptive response.	Environmental motivations for migration
Wu (2011) (196)	Chinese Academy of Sciences (China), Wayne State University (USA), East China Normal University (China), University of Science and Technology of China (China)	Policy, Management, Geography, Urban Planning	Journal of Historical Geography	To simulate the spatial evolution of the population of China over the past 2000 years.	Migration demographic or regional

For each study, the aim defines how to calibrate the model (choosing the data sources and applying various data sources to different elements of the model) and how to develop the model (the time, space, agents and environment, as well as the model decision rules). The included studies present a range of exploratory aims, which we have grouped into seven broad sub-categories: migration demographic or regional trends; environmental motivations for migration; migration theory testing; humanitarian migration trends; the social influence on migration patterns; the individual economic utility of migration; and slavery. The two most frequent research categories were: exploring the environmental motivations for migration, such as climate change, environmental shocks or land-use changes (n=10); and explorations of migration corridor trends by geography or demographics (n=5). The other study aims fell into the following categories: humanitarian migration trends (n=4); social influences on migration patterns (n=4); migration theory testing (n=3); individual decision making based on the economic utility of migration (n=1); and the diffusion of slavery (n=1). None of the studies explicitly aimed to understand various migration pathways and individual processes of migration, since most were focused on macro-drivers of migration trends, such as expected wage differentials, weather conditions or humanitarian situations.

2. Model inputs

Most studies used multiple types of data (theory, primary, secondary, historical, cited research, reports, etc.) to calibrate the model parameters, initial settings, environmental characteristics, scenarios or decision rules (Table 10). Recently the computational social science community has begun to devote more attention to empirical calibration and validation of ABMs (199), where previously the vast majority of ABMs have been calibrated solely as thought experiments using theory. In this review, 5 articles reported using primary empirical data for ABM calibration and 11 studies

used secondary data sources (excluding GIS data, historical climate data, or cited research findings as 'secondary data'), an approach that some have called an 'indirect strategy' for empirical calibration that is a limited but promising option when collecting primary empirical data is not feasible. The notable difference between the studies that used primary versus secondary empirical data is that all 5 studies that collected primary data used the analysis of this data to inform individual behavioural rules in the model (e.g., how migrants decide to migrate) but only 5 (of 11) of the studies that only used secondary data sources did so to inform individual behavioural rules. Both primary and secondary empirical data sources were used to inform agent attributes (n=2), population size and attributes (n=4), population trends (e.g., migration flows, household crop yields, household spending) (n=5), social networks (n=1), regional land use (n=3) and key events (e.g., natural disasters, conflicts) (n=2). The use of empirical and secondary data sources in this review reflects the wider trends in empirically calibrated ABMs, which is that it is usually more common to find secondary data that can inform the model structure components (types of agents, number of agents, environmental characteristics) but less common to find secondary data sources that offer the rich data on behaviours and interactions that are often so central to the theoretical research questions (199).

Most commonly (n=21), the ABM decision rules, or assumptions were informed by theory, primarily from economics, psychology or theoretical developments in the field of migration studies. In fact, 9 of the ABMs exclusively used theories to calibrate the models, such as theories on the push and pull factors of migration or the influence of social networks on migration, to calibrate the model, as can be reviewed in Table 10. This is not surprising given the scarcity of migration data collected from a complex systems approach that would be easily translatable to ABMs. For example, ABMs modelling labour migration as a complex system would need data on migrants' social networks' role in the migration process, the interactions

between migrants and the wider systems environment, or the decision-making process of migrants, labour intermediaries and employers. There is a high burden to collecting this kind of data in any setting, and there are additional challenges in research with a largely hidden and mobile population, such as low-wage international migrant workers or human trafficking victims (200, 201). Boero and Squazzoni point out that despite the challenges to missing, incomplete or scarce data in many fields of research, the valuable theoretical constructs produced using ABM methods need to be embedded in empirical findings (at both calibration and validation stages of model development) so that the theoretical mechanisms are empirically grounded in the real-world phenomena (199).

Studies that employed secondary datasets (n=15) sourced the datasets from various federal and municipal governmental departments, as well as national and international non-government organisations, such as the World Bank or United Nations (170, 182, 183, 186, 187, 192). For spatial calibration of the model, eight ABMs used some type of GIS data. Only one study used participatory methods in calibrating the model with key stakeholders by hosting ABM workshops at various stages in the model development (185). Additional data sources included in-depth case studies, secondary research findings in the literature, non-peer-reviewed reports and historical trends in weather or migration (Table 10). The models pulled from a wide range of theoretical knowledge and empirical analysis to inform model development and decision model choices. For example, the range of theory and background analysis included psychology-based theories of wellbeing and decision making, information diffusion, cooperation theory, systems theory, social network theory, topics in microeconomics, game theory and a range of topics pertaining to migration push-pull factors (Table 10).

The model's data inputs often determine the decision model used in an ABM. An ABM can employ more than one decision model, such as a combination of simple heuristics (breaking down agent actions into simpler

if/then rules) and decision theory (generalised knowledge on human's reasoning and process in making decisions) or microeconomics utility maximisation (the aim is maximising profits or payoffs- such as wage differential motivated migration). Or in some cases, there might be some use of empirical data, but the data are often insufficient to inform all the decision-making processes so theoretical knowledge is used in combination with empirical observations. For example, Alghais used primary empirical survey data from urban residents in Kuwait on their residential preferences to determine empirically informed decision-rules for why, when and where individual agents would migrate to new urban centers (169). Decision making was also the primary focus of Klabunde and Willekens's review and they give an extensive description of the different decision models currently being used in migration ABMs similar to the decision-models described above. This review borrows some of Klabunde's decision model categorisations in Table 10 (134). All eight studies that collected primary data also incorporated these data into the ABM's decision model. Microeconomic utility maximisation has been a longstanding theory applied to the study of migration motivations and decision-making and was used to model decision making in 12 of the included studies (Table 10). As Klabunde and Willekens's review points out, there are also key theories pertaining to both individual and group decision-making and pyscho-social and cognitive behavioural science that are increasingly being applied to the study of migration, such as the Theory of Planned Behaviour (134). In our review, four studies described the using a range of specific decision making theories in their decision model choices, which covered broad topics of well-being (170), management (172), cumulative causation including the role of social influences (175), and game theory (180). Additionally, both of Kniventon et. al. studies applied the Theory of Planned Behaviour (182, 183), which is considered a psycho-social and cognitive theory and described in further detail in Klabunde and Willekens's review (134). Three other studies described the use of a psycho-social and cognitive theory in the decision

model. The psyco-social and cognitive theories incorporated the influence of climate-change (177), the herd effect (188), and a combination of bounded rationality and social feedback (191). A commonly used decision model was simple heuristic models (n=13) that were not always informed by any primary empirical findings nor based-off clearly defined theoretical knowledge.

Table 10. Model inputs

First Author (Year)	Data type(s) [listed alphabetically]	Data source(s)	Theory basis or relevant background themes	Decision model(s) [listed alphabetically]
Alghais (2018) (169)	primary empirical, GIS, reports, secondary	(1) Residential survey data sent via social-media (2) Kuwait Institute for Scientific Research population data (3) Kuwait Finance House Real Estate Reports for housing costs (4) ArcGIS Near tool (5) Public Authority for Civil Information demographic data (6) Kuwait Municipality plans and interviews for new city data	migration push–pull factors, segregation, urban planning policy	(1) empirical observations
Anderson (2007) (170)	secondary, theory	(1) Literature on wellbeing and microeconomics (2) UN Refugee Agency datasets	well-being theory, microeconomic production and consumption theory, information diffusion, social network theory, systems theory	(1) decision-making theory (well-being) (2) heuristics (3) microeconomic expected utility
Cai (2015) (171)	theory	(1) Literature on systems science and economics	consensus theory, dynamic multi-agent systems theory	(1) microeconomic expected utility
Chesney (2019) (172)	theory	(1) Literature on modern slavery as a management practice	modern slavery as a management practice theory (Crane), nexus of labour exploitation and sustainable business	(1) decision-making theory (management theory) (2) heuristics (3) microeconomic expected utility
Entwisle (2016) (173)	GIS, secondary, theory	(1) Nang Rong project survey and ethnographic data (2) University of Delaware Center for Climate and Land Surface Change 1900-2008 Nang Rong datasets (3) Thai Rice Exporters Association 2000 Nang Rong crop market prices datasets (4) Literature on neo-classical economics theories of migration (5) GIS maps	migration push–pull factors, neo-classical economic theories of migration, sociological theories of migration	(1) empirical observations
Espındola (2006) (174)	historical, theory	(1) Literature on two-sector (rural and urban) economic theories and production theories (2) Literature on historical trends in developing economies	migration utility maximisation theory, production function theory	(1) microeconomic expected utility

First Author (Year)	Data type(s) [listed alphabetically]	Data source(s)	Theory basis or relevant background themes	Decision model(s) [listed alphabetically]
Fu (2018) (175)	secondary, theory	(1) Literature on other ABMs that explore the economics of migration (2) Literature on probability theory (2) 2000 China Census	theory of cumulative causation of migration, substantive theories (causes of migration)	(1) decision theory (cumulative causation) (2) empirical observations (3) heuristics (4) microeconomic expected utility
Garcia- Diaz (2012) (176)	theory	(1) Literature on economic and labour theories	social network theory, utility maximisation theory	(1) Ising model (discrete choice)
Hailegiorgis (2018) (177)	GIS, historical, theory	(1) Literature socio-cognitive behavioural theories (2) Historical rainfall data for Ethiopia 1901-2009 (3) GIS data	protective motivation theory, socio-cognitive behaviour	(1) heuristics (2) psycho-social and cognitive (climate change)
Hassani-Mahmooei (2012) (178)	cited research findings, secondary, theory	(1) Bangladesh Bureau of Statistics data on migration flows (2) Secondary research on Bangladesh district boundaries demographic variables economic variables and development variables. (3) GIS data (4) Literature on migration decision making specific to the Bangladesh context and more broadly.	migration threshold theory	(1) heuristics
Henry (2017) (179)	theory	(1) Literature on economic theories related to common-pool resource use and cooperation.	cost/benefit and present/future payoffs, theory of discount rates and resource exploitation, game theory	(1) heuristics (2) microeconomic expected utility
Ichinose (2013) (180)	theory	(1) Literature on the evolution of cooperation and the Prisoner's Dilemma game	Prisoner's Dilemma, cooperation theory, coevolutionary games	(1) decision-theory (game theory)
Janssen (2010) (181)	case studies, historical, theory	(1) Literature on social–ecological systems (2) Palmer Drought Severity Index historical SW USA rainfall data	climate-induced migration, population dynamics	(1) heuristics (2) microeconomic expected utility
Kniventon (2011) (182)	primary empirical, secondary, theory	(1) Literature on climate change induced migration (including other ABMs) (2) Enqueˆte Migration Insertion Urbaine et Environnement au Burkina Faso (EMIUB) nationwide representative survey dataset (3) Focus group interviews conducted across Burkina Faso (4) United Nations World Population Prospects projection data (5) European Centre for Medium Range Weather Forecasts. (6) Literature on the Theory of Planned Behaviour.	multi-causal migration theory, individual agency, theory of planned behaviour	(1) psycho-social and cognitive (Theory of Planned Behaviour)

First Author (Year)	Data type(s) [listed alphabetically]	Data source(s)	Theory basis or relevant background themes	Decision model(s) [listed alphabetically]
Kniventon (2012) (183)	primary empirical, theory	(1) Enqueˆte Migration Insertion Urbaine et Environnement au Burkina Faso (EMIUB) nationwide representative survey dataset (2) ENSEMBLES project climate projections. (3) Literature on the Theory of Planned Behaviour.	theory of planned behaviour	(1) empirical observations (2) psycho-social and cognitive (Theory of Planned Behaviour)
Mena (2011) (184)	cited research, GIS, satellite imagery, secondary	(1) Longitudinal and cross-sectional farm and household survey data (2) 1986 LULC classification of Landsat TM satellite imagery dataset (3) Ecuadorian GIS maps (4) Literature on migration	environmental migration, complexity theory	(1) empirical observations
Naivinit (2010) (185)	primary empirical, historical, secondary	(1) Participatory ABM building workshops with stakeholders (2) Qualitative interviews and focus group discussions (3) Survey with farmers (4) Bangkok National Statistical Office Ministry of Information and Communication Technology (5) Bangkok Office of Agricultural Economics Ministry of Agriculture and Cooperatives (6) Historical rainfall data(1986-1995) (7) Historical Thai Rice Mills Association rice market prices.	participatory methods	(1) empirical observations
Naqvi (2014) (186)	cited research, GIS, secondary, theory, secondary	(1) Literature on low-income economies (2) Pakistan Household Expenditure Survey (3) Pakistan Agriculture Census of 2010 (4) Food and Agriculture Organization (5) World Bank (6) Federal Bureau of Statistics Government of Pakistan (7) Pakistan GIS maps	utility maximisation migration theory, gravity model of migration	(1) heuristics (2) microeconomic expected utility
Naqvi (2017) (187)	cited research, GIS, reports, secondary, theory	(1) Literature on micro household adaptation strategies in the face of natural disaster-like shocks (2) Food and Agriculture Organization (3) Asia Development Bank (4) World Bank (5) Federal Bureau of Statistics Government of Pakistan (6) Pakistan GIS maps (7) United Nations	micro-adaptation strategies, natural disasters, economic loss models	(1) heuristics (2) microeconomic expected utility

First Author (Year)	Data type(s) [listed alphabetically]	Data source(s)	Theory basis or relevant background themes	Decision model(s) [listed alphabetically]
Raczynski (2018) (188)	theory	(1) Literature on gregarious effect and other migration theories	herd behaviour	(1) heuristics (2) microeconomic expected utility (3) psycho-social and cognitive
Silveira (2006) (189)	theory	(1) Literature on rural-urban migration theory	expected utility theory, rural–urban migration theory, production function	(1) Ising model (discrete choice)
Simon (2019) (190)	secondary, theory	(1) Mexican Migration Project dataset 1990-2013 (2) Literature on small world network topology (3) Literature on social network theory and new economics of labour migration theory	social network theory, new economics of labour migration (target savings)	(1) microeconomic expected utility
Smith (2014) (191)	primary empirical, secondary, historical, theory	(1) 'Where the Rain Falls' survey data in Tanzania (2) Meteorological Station data (1950 & 2010) (3) Literature on climate change and migration	bounded rationality theory, theory of planned behaviour	(1) heuristics (2) psycho-social and cognitive (bounded rationality and social feedback)
Suleimenova (2017) (192)	GIS, secondary	(1) Armed Conflict Location and Events Database (2) UNHCR camp population datasets (3) GIS road data from Bing Maps	conflict affected migration	(1) empirical observations (2) heuristics
Tabata (2003) & (2004)* (193, 194)	theory	(1) Literature on the interregional migration theory and the socio-economics of migration.	bounded discrete domain, theory of interregional migration, socio-dynamics	(1) microeconomic expected utility
Walsh (2013) (195)	primary empirical, GIS, secondary	(1) Longitudinal social survey of ~10 000 households (2) Archive of satellite images to characterise land use/land cover change trajectories (3) Thailand GIS maps	land change science, decision under uncertainty	(1) empirical observations
Wu (2011) (196)	cited research, secondary	(1) Research findings on historical temperature and precipitation (2) Research on China's historical migration waves (3) Scientific Databases of China	social network theory	(1) heuristics (2) microeconomic expected utility
*The models presented in Tabata's 2003, and 2004 papers are identical by most of the points extracted for this review.				

3. Model development

ABMs incorporate the attributes and interactions of agents, time, space, environment and in some cases social networks and exogenous factors. The majority (n=21) of the included studies defined the time-steps in terms of real time ranging from one-hour to five-years and the time horizons ranging from four-days to 10,000-years (Table 11). The 10,000-year time-horizon was a far outlier since it was a historical anthropological migration study. Most of the studies had time-horizons that were 50 years or shorter. Seven of the studies used time-scales that reflected real historical or date ranges, primarily in years, such as Kniventon, Smith and Black's model on climate induced migration in Tanzania from 1970-1994 (183). The remaining models that included clear explanations of time-steps (n=4) represented these discrete increments as 'time-to-event' meaning that they represented distinct processes, such as farming seasons or migration cycles (174, 176, 179, 180).

Spatial characteristics are often an important design decision in ABM and the spatial representation depends on the research aims and data available (Table 11). Some used abstract spatial representations such as grids or networks (n=14), some used artificial constructs such as a refugee camp setting or generic farm landscapes (n=4), and finally some used real spaces often mapped using GIS data (n=9). One study did not describe the spatial elements in enough detail to classify.

Along with time and space, deciding the agents and respective attributes is key to ABM development. Often the aim is to make models as complex as they need to be but no more, often referred to in the ABM modelling community as Occam's Razor principle or the KISS principal ('Keep It Simple, Stupid') (202). This can be a difficult aim to achieve when deciding how many distinct agent-types are needed and what attributes are required for the various decision making processed and interactions included in the model processes. Most of the models included in this review only have one type of

agent (n=15), sometimes named as migrants, or workers. Some models include a second or third type of agent, such as employers, landowners, leaders, or government agents and still some models used secondary groupings of individual agents to represent households or villages with their own unique attributes (Table 11). Most often, these agents have a range of heterogeneous attributes, such as demographics, socio-economics, propensity to migrate or act, assets, etc., but in three of the studies, agents were only characterised and distinguished by location and not by any additional attributes (193, 194, 196).

The models also described various exogenous or environmental characteristics that impacted on the parameters of the model or the agent's behaviour within the model. Some examples included, location-specific variables such as population levels, services available, distance to travel, wage-differentials, housing capacity at destinations, etc. (Table 11). A common exogenous factor was weather or climate (n=8), often varying across scenarios or time-steps. Finally, some demographic and epidemiological rates were defined at the population level, such as birth rates, death rates, migration rates, sickness rates, etc. These exogenous or environmental factors are not within the individual agents' control and reflect the larger system(s) that these migration- or work-related decisions are taking place within. Another broader model characteristic that impacts individual agent actions are the social networks that agents can be grouped into, such as households, villages, intra-group networks, and non-spatial social networks. A majority (n=21) of the studies used some type of agent grouping or network in addition to individual agents (Table 11).

Table 11. Model development

First Author (Year)	Time-steps, Time-horizon	Spatial characteristics	Agent Types: Agent attributes [micro characteristics]	Exogenous or environmental characteristics [macro characteristics]	Social networks [meso characteristics]
Alghais (2018) (169)	5-years, 35-years (Real years: 2015 to 2050)	Real: Kuwait city and surrounding urban districts	(1) Resident Agents: nationality, age group, servant or non-servant, migration preferences, household size (2) Household Agents: size, nationality	(1) Districts: type (residential, mixed or other uses), population capacity, suitability parameters, existing services, location (2) Migration push and pull factors: land/property value, housing shortages, commuter traffic and accidents, public services, employment, house size (3) Government planning authority	(1) Households: groups of individual agents
Anderson (2007) (170)	One-hour, 4-days	Artificial construct: Virtual model of a refugee camp	(1) Refugee (Citizen) Agents: health, medical centre attendance, socio-economic status, well-being, needs, religion, ethnicity, ideology, time till death, (2) Leader Agents: [same attributes as refugee agent], level of influence, type of influence, ideologies, opinions (3) Governmental Agents: type (army, police, legislature, executive, politicians, etc.)	(1) Medical centre: capacity, probability of death (2) Community level: sanitation, food supply, water supply, medical resources, medical personnel, security (3) Social influences: organizations, leaders, media (4) Population: probability of sickness	(1) Organizations: structured group of citizens (members) and leader agents- the combined behaviours and interactions of members and leaders results in the behaviour for the organization (2) Intra-group Social Networks: members can form levels of affinity towards each other and influence each other's attitudes (3) Inter-organization Networks: organizations can share attitudes and resources
Cai (2015) (171)	One-day, 30-months	Abstract: Two-sectorial urban-rural economy	(1) Worker Agents: propensity to migrate, perspective of wage differential	(1) Quantity of firms and farms (2) Wages	(1) Random social graph topology

First Author (Year)	Time-steps, Time-horizon	Spatial characteristics	Agent Types: Agent attributes [micro characteristics]	Exogenous or environmental characteristics [macro characteristics]	Social networks [meso characteristics]
Chesney (2019) (172)	One-day, 200-days	Abstract: Social network (not described in detail)	(1) Employer Agents: number of workers needed, number of workers employed, wages paid, profits, employment reach (2) Workers Agents: job status, length of unemployment, movement ability, tolerance for low pay	(1) Industry labour demands	(1) Employer Network: Links between employers representing lines of communication between neighbouring farms- an employer's number of neighbours impacts the wage changes based on wage comparisons (2) Worker Network: Links among workers representing workers meeting and sharing information with each other
Entwisle (2016) (173)	One-year, 25-years	Real: Nang Rong, Thailand	(1) Individual Agents: demographics, probability of in-migration, probability of out-migration (2) Household Agents: assets, land ownership, centrality in village networks, number of ties to wealthy households (3) Village Agents: aggregate of household and land parcel attributes, population size, migration prevalence	(1) Land parcels: status (owned/ managed/ used), size, distance from village, flooding potential, land use, soil suitability, productivity (2) Climate conditions (3) Population: migration probabilities	(1) Households: made up of individuals (2) Villages: groups of households (3) Social Networks: ties among households or villages
Espındola (2006) (174)	Time-to-event, 100-time-steps	Abstract: Two-sectorial urban-rural economy	(1) Worker Agents: location, employment, wages, satisfaction level	(1) Urban share of environment (2) Landscape quality (3) Minimum wage	not described
Fu (2018) (175)	One-month, 5-years (Real years: Jan 1996- Dec 2000)	Abstract: Social network on a matrix grid	(1) Individual Agents: demographics, education, origin, migration status, destination, propensity to migrate	(1) Provinces: type (rural/ urban), local economy	(1) Social Network with various levels: empirical and theory-based family ties, ties within villages, ties between villages, ties between migrants

First Author (Year)	Time-steps, Time-horizon	Spatial characteristics	Agent Types: Agent attributes [micro characteristics]	Exogenous or environmental characteristics [macro characteristics]	Social networks [meso characteristics]
Garcia- Diaz (2012) (176)	Time-to-event, ~150-time-steps (not clearly described)	Abstract: Lattice grid with 8-cell neighbourhoods	(1) Migrant Worker Agents: demographics	(1) Work sectors: type, quantity, expected and actual wages, goods prices, probability of employment, labour-to-output elasticity, labour supply (2) Population: social influence, migration probability	(1) 8-cell neighbourhoods: influencing factor on migration decision making
Hailegiorgis (2018) (177)	One-day, ~50-years (18,250 time-steps)	Real: South Omo Zone, Ethiopia	(1) Household Agents: land, crop and livestock production, climate prediction, ingenuity level, learning rate	(1) Climate: cost of adaptation, risk elasticity (2) Herding: consumption rate, livestock price, destocking rate, livestock growth rate (3) Farming: costs, labour efficiency (4) Vegetation: rainfall minimum, vegetation hectares (5) Population: number of households (6) Demographic changes: birth and death rates	not described
Hassani-Mahmooei (2012) (178)	One-month, 50-years	Real: Networked districts, Bangladesh	(1) Individual Agents (representing group of people): migration threshold	(1) Districts: socio economic development, population density, climate shock vulnerability (2) Climate changes (3) Population: socioeconomic changes (by location)	(1) Agent-to-Agent Links: individual-level interactions and perceptions of social networks affects agents' adaptation decisions
Henry (2017) (179)	Time-to-event, ~150 (time-steps not clearly described)	Abstract: Singular grid (size unspecified) representing one shared resource area	(1) Individual Agents: level of group cooperation, value of future payoffs, maximum harvest, cost of living, wealth	(1) Resources: discount rate, maximum unit withdrawal, minimum harvest, resource stock, growth rate, defector harvest monitoring (2) Demographic changes: birth and death rates (3) Population: altruism	(1) Common Pool Resources (CPRs): a collection of agents that depend upon a shared natural resource
Ichinose (2013) (180)	Time-to-event, 10,000-time-steps	Abstract: Lattice grid with 8-cell neighbourhoods	(1) Individual Agents: type (co-operator or defector)	(1) Population level: density, temptation to defect	(1) 8-cell neighbourhoods
Janssen (2010) (181)	One-year, 10,000-years	Abstract: Torus grid with 400-cells	(1) Individual Agents (represent group of people): location, food storage available, length of food storage, debt, debt tolerance, sharing strategy, migration threshold	(1) Climate and soil: rainfall, soil degradation, soil regeneration (2) Resources: depletion rate, production, minimum food, maximum debt, storage time, storage loss, learning factor (3) Migration: expectation threshold, opportunities, minimum buffer (4) Demographic changes: birth and death rates (4) Cells: production quality	(1) Settlement: more than one agent in a cell- agent to agent resources sharing (2) Settlement Network: settlement to settlement links- settlements exchange resources when one or more settlements experience shortages

First Author (Year)	Time-steps, Time-horizon	Spatial characteristics	Agent Types: Agent attributes [micro characteristics]	Exogenous or environmental characteristics [macro characteristics]	Social networks [meso characteristics]
Kniventon (2011) (182)	One-day, 50-years	Real: Burkina Faso (all regions)	(1) Individual Agents: demographics, assets, context, previous experiences, perceived peer opinions, perceived behavioural control, biases	(1) Climate conditions (2) Asset distribution (3) Demographic changes: birth and death rates (4) Origin: population size, season, rainfall (5) Destination: population size, choice	(1) Agent-to-Agent Links: information is shared amongst agents- preferences of peers may influence decision making
Kniventon (2012) (183)	One-year, 25-years (Real years: 1970-1994)	Real: 5 regional zones, Burkina Faso	(1) Individual Agents: demographics, location, probability of migration (by zone), previous experiences	(1) Climate conditions: rainfall	(1) Small-World Network: each agent linked to fifty other agents defined at start-up- agents inform each other on their migration decisions and peer opinion values are derived for each of the migration options being considered
Mena (2011) (184)	One-year, 25-years (Real years: 1990-2015)	Real: Lattice grid laid over Ecuadorian Amazon	(1) Individual Agents: demographics, household	(1) Landscape (cells grouped into 'parcels' and parcels grouped into 'farms'): land ownership, land use, physical environment, landscape type (2) Historic prices: agriculture (3) Demographic changes: birth and death rates	(1) Households: made up of individual agents, one on each farm
Naivinit (2010) (185)	One-day, 10-years	Artificial construct: Farm environments consisting of paddy fields and human settlements (houses, village, city)	(1) Individual Agents: demographics, migration experience, labour status (2) Household Agents: farmer type, income, farm input cost, annual area of paddy for self consumption (3) Village Agents: daily wages paid	(1) Demographic ranges: ages for farmers and migrants (2) Land: transplanted and harvested areas, transplanting thresholds, rainfall thresholds, wages, group (early or late-maturing), crop stages and dates, average paddy yield, age of seedlings, duration of transplanting dates, prices for various paddy qualities, water quantity threshold (3) Water tanks: soil-plant system deductions, minimum depth, actual depth, height of ponding tanks, water level	(1) Households: groups of individual agents (2) Villages: groups of households

First Author (Year)	Time-steps, Time-horizon	Spatial characteristics	Agent Types: Agent attributes [micro characteristics]	Exogenous or environmental characteristics [macro characteristics]	Social networks [meso characteristics]
Naqvi (2014) (186)	One-day, 360-days	Artificial construct: Representation of Pakistan region with spatially defined cities (3) and villages (9) connected via a road network	(1) Owner Agents: self-producing labour, money, capital stock, food/tradable goods, wages paid (2) Worker Agents: employment labour, money, food/tradable goods	(1) Land: production capacity (2) Employment: total hired workers, wages	(1) Agent-to-Agent Interactions: either within a location (village or city) or across locations
Naqvi (2017) (187)	Half-day, 600-days	Abstract: Lattice grid with overlaying road network (Pakistan GIS road map)	(1) Individual Agents: location, income, savings, food supply	(1) Road network: routes, bottlenecks, distances (2) Locations: villages or cities with stocks of workers (3) Earthquake fault line, damages, labour losses, capital losses (4) Population: worker productivity, access to information (5) Market factors: market selling prices, wages	not described
Raczynski (2018) (188)	One-day, 2,190-days & 7,390-days	Artificial Construct: Fictitious region (8 named sub-regions: California, Manhattan, Yellowstone, Illinois, Acapulco, Los Angeles, Alaska, and London)	(1) Individual Agents: ethnic group, information, location, migration memory, migration threshold, migration cost threshold	(1) Demographic changes: birth and death rates (2) labour market: migrant influx, job opportunities (3) Region: population (per ethnicity), security, water and electricity supply, drainage, paving, technology, climate, infrastructure, services, jobs (4) Organization influencers: type (social, religious, or political structures), impact on migration	(1) Social/Ethnic Groups: demographics, literacy levels, bilingual levels, economic levels, birth and death rate
Silveira (2006) (189)	Not clearly described, ~50-100-time-steps	Abstract: Lattice grid with two-sectorial urban-rural economy where cells represent sector-type not spatial distribution	(1) Worker Agents: sector, utility of migration	(1) Urban manufacturing: firm output, total employed workers, worker effort, equilibrium unemployment rate, urban population, manufactured goods prices, scarcity of manufactured goods, job allocation (2) Rural farming: real wages, rural population, agricultural goods prices, scarcity of agricultural goods	(1) Social Neighbourhoods: workers are influence by their nearest neighbours

First Author (Year)	Time-steps, Time-horizon	Spatial characteristics	Agent Types: Agent attributes [micro characteristics]	Exogenous or environmental characteristics [macro characteristics]	Social networks [meso characteristics]
Simon (2019) (190)	One-year, 24-years	Abstract: Social network (not described in detail)	(1) Individual Agents: origin, location, wealth, consumption, total savings, previous migrations, expected wage value, wage at destination, remittances, utility of returning to origin	(1) Wages: wage assignments, wage variables, immigrant labour supply, wage competition, wage equilibrium (2) Migration: immigration policy, financial costs of migration, cost of return, probability of migrant entry to destinations	(1) Small-World Network: high clustering like regular networks but also small path lengths like random networks, all ties are strong, median number of ties is 6 (2) Agent-to-Agent Interactions: individuals abroad relay information on wage variables to network ties at home to derive utility calculations, migrants send remittances, agents at origin can only obtain information about host country conditions from the migrants they are connected to through network ties
Smith (2014) (191)	One-month, 30+ years (Real years: 2015-2047)	not described	(1) Individual Agents: demographics, migration history, propensity to migrate, migration attitudes (2) Household Agents: land, economic activity, crop and livestock yields for consumption and sale, income, savings, employed members, employment level, dependency ratio, migrant members, sum of migration experience, migrant remittances, permission for members to migrate	(1) Climate: rainfall (2) Changes to labour markets and food production (3) Demographic changes: birth and death rates	(1) Households: groups of individuals (2) Social and Farm labour Networks: allows agents to share views on migration and a means to distribute farm labour between members of the community through household-to-household communication

First Author (Year)	Time-steps, Time-horizon	Spatial characteristics	Agent Types: Agent attributes [micro characteristics]	Exogenous or environmental characteristics [macro characteristics]	Social networks [meso characteristics]
Suleimenova (2017) (192)	One-day, Burundi: 396 days (1 May 2015 - 31 May 2016), CAR: 820 days (1 Dec 2013 - 29 Feb 2016), Mali: 300 days (29 Feb 2012 - 25 Dec 2012)	Real: Geographic maps of conflict locations, roads and camps in Burundi, CAR and Mali	(1) Refugee Agents: probability of migrating, location	(1) Environment: routes, road length, border points, border closures, location types, location attractiveness, forwarding hubs	not described
Tabata (2003) & (2004)* (193, 194)	not described	Abstract: Discrete sections (not clearly described)	(1) Individual Agents: location	(1) Cell characteristics: density of agents, utility of cell (2) Cost of migration	not described
Walsh (2013) (195)	One-year, 25-years	Real: Geographic map of Nang Rong District	(1) Individual Agents: demographics, migration status	(1) Landscape (cells grouped into 'parcels' and parcels grouped into 'farms'): land ownership, land use, physical environment, landscape type (2) Historic prices: agriculture (3) Demographic changes: birth and death rates	(1) Kinship Networks: the first-degree links are an individual's parents and spouse- then additional social network ties are created through matrix multiplication. (2) Household Networks: aggregation of kinship networks
Wu (2011) (196)	One-year, 2,002-years (Real years: 2 A.D.- 2003)	Abstract: Lattice grid with 227x297 cells in 8/16/24 cell neighbourhoods, Residential Unit cells and River cells	(1) Individual Agents: location	(1) Residential units: state (null, potential, existent), population size (2) Provinces: agriculture productivity, area availability, population (3) Migration rate (4) Sub-systems: social influencers, climate, agriculture	not described
*The models presented in Tabata's 2003, and 2004 papers are identical by most of the points extracted for this review.					

4. Model process

The model process takes on a unique form for every ABM. It would be impossible to fully synthesise the initialization, model steps, decision rules, agent actions and scenario descriptions across all 28 studies in a meaningful way. We recommend the reader inspect the columns of Table 12 to get an overview of the design of the model process as it is simulated in each model. Most of the models are initialised by constructing the real or abstract spatial setting and populating it with agents set with initial attributes and locations. A commonly repeated theme throughout the models is that an agent primarily decides whether to migrate, where to migrate and then attempts to execute migration. In most cases, this decision to migrate is based on a microeconomic utility function, as described in Table 12. Most of the studies (n=22) included a variation of 'scenarios' which usually entailed changing exogenous elements or altering decision rule variables, most commonly this was changes in weather scenarios, but in some cases is was not weather-related, such as differences in employee wages (172) or differences in urban development plans (169).

Table 12. Model process

First Author (Year)	Initialisation	Model Steps and Decision Rules	Agent Types: Agent actions	Scenario simulation	Deterministic or stochastic
Alghais (2018) (169)	(1) GIS spatial data and demographic data are input; population projections are loaded (2) The model schedule is set to begin in 2015 (3) New cities and the districts are assigned suitability weights and threshold for opening the new cities (4) New residents are allocated to old districts with available housing capacity (5) ABM user selects which scenario (1-3) will be simulated	(1) Establishing a new city (2) Migration: Resident agents move from the old urban area to the selected city (3) Segregation distribution: After the end of each time step the nationality segregation level will be calculated and the output map will be updated	(1) Resident Agents (above 18 and not servants): decide whether to migrate, choose destination, migrate (2) Teenagers and Servants: follow household decision	(1) Government scenario: Simulates the urban development of new cities based on the government's plans alone. (2) Resident scenario: Simulates urban development of new cities based on the resident preferences, segregation is simulated according to the resident responses, (3) Global Cities scenario: Simulates urban development of new cities based on the resident preferences, segregation is simulated according to the Global Cities plan	deterministic

First Author (Year)	Initialisation	Model Steps and Decision Rules	Agent Types: Agent actions	Scenario simulation	Deterministic or stochastic
Anderson (2007) (170)	(1) Agent's desire of each need is initially based on the socioeconomic class of the citizen.	(1) Agents and networks interact and exchange influence (2) Citizen Agents remain in one of four health states for a minimum of one-time step and each time step they check to see if they should transition to another health state (3) Citizen Agents perceive their need satisfaction and adjust weights as certain needs become more significant	(1) Citizen Agents: motivated by individual traits and well-being, receive information, perceive needs, assess deprivation of needs, adjust weights of needs based on the environment, focus on attaining most deprived needs, transition between health states, enter Medical Centers, die (2) Leader Agents: influence ideologies (3) Media Organization Agents: report information, set policy agenda	not described	deterministic
Cai (2015) (171)	(1) Social graph topology is generated randomly (2) Initial ratio of urban population is set to 20%	(1) Each worker reviews their situation and decides whether to migrate or stay, (2) Some workers migrate, (3) Some emigrating individuals die and some settle at ransom in one of the 8 nearest cells to their origin cell.	(1) Worker Agents: review situation, decide whether to migrate, migrate	not described	stochastic: network links

First Author (Year)	Initialisation	Model Steps and Decision Rules	Agent Types: Agent actions	Scenario simulation	Deterministic or stochastic
Chesney (2019) (172)	(1) Set number of workers and employers populate model and no one is initially employed (2) A randomly selected employer begins model process by offering work to workers within his proximity vision (3) Employers' wage levels are set randomly to start	(1) Employers ask workers if they want to work, (2) Workers decide on whether to accept or refuse work offer based on their length of unemployment and experience with the Employer. Workers accept any offer from an employer who they believe will pay at least as high a percentage of the minimum wage as their tolerance. (3) Employers should pay every worker a minimum wage, but some pay less than this by making unreasonable reductions or simply refusing adherence to minimum wage. The decision on what to pay comes from the employer's perceived legitimacy of paying under the minimum wage, which is determined by (a) what neighbouring employers pay and (b) whether they can employ their full workforce from their potential workforce, which is the number of workers within their locality. Employers' heteronomy moderates both. (4) There is a probability of workplace inspection each time-step and if an Employer is found to be paying illegal wages they are shut down and replaced with a new Employer. (5) Revenue is calculated for that time.	(1) Employer Agents: make job offers, set wages, interact with neighbour employers, assess neighbour employer wages, assess workers in proximity (2) Worker Agents: accept or reject job offers, move locations, share information with workers, learn the reputation of employers	(1) Presence of an employer that always pays below minimum wage, (2) Presence of an employer that always pays above minimum wage	stochastic: probability of visit from labour inspector

First Author (Year)	Initialisation	Model Steps and Decision Rules	Agent Types: Agent actions	Scenario simulation	Deterministic or stochastic
Entwisle (2016) (173)	(1) Village, household and individual agents are populated in the model, (2) Land parcels and cells attributes are assigned by GIS data, (3) All attributes are set as null initially, (4) Social data is created using socio-mix (parent/child and spouse/spouse)	(1) Each household makes a choice about how to use its land parcels (for rice, sugar, or cassava cultivation) and inputs such as fertilizer. (2) Annual crop productivity is determined based on crop type, soil type and quality, amount of rainfall and planting time, and fertilization levels. (3) Crop yields influence household income, (4) Household income affects accumulated assets, (5) Assets affect migration probability, (6) Out-migration is a result of individual probability compared to a random number and if the probability is higher than random number the individual migrates, (7) If a parent dies then assets go to a randomly selected child of that parent, or next to any child in the village, or to any living migrant or to the closest relatives. (8) If the risk of household split is positive then new household is created with 15% of original households assets and then is assigned a randomly set land split trigger value.	(1) Individual Agents: born, marry, give birth (female agents only), die, migrate, return home, establishing new local residence, send remittances (2) Household Agents: rent or own land, accumulate assets, pass assets to kin when they die or reach old age, choose how to use land parcel, apply appropriate fertilizer	(1) Reference ‘‘normal weather’’ scenario, (2) 7 years of unusually wet weather, (3) 7 years of unusually dry weather, (4) 7 years of extremely variable weather, (5) Remove individual characteristic effects from the model, (6) Remove remittance transaction effects from the model, (7) Remove social network effects from the model, (8) Allows households to adapt to consecutive years of extreme climate and income losses	stochastic: probability for migration
Espındola (2006) (174)	(1) Workers are randomly placed in a square lattice (2) The initial value of the minimum wage is set to zero (3) The initial urban fraction of the total population is 20% (4) The potential migrant starts the comparison process with an initial satisfaction level set to zero	(1) Agents assess their current situation and consider migration options, (2) Agents choose whether to migrate based on wage differentials, (3) Agents migrate (if they decided to), (4) A new configuration of the system is set. *The whole procedure is repeated until a pre-set number of steps is reached.	(1) Worker Agents: review sectorial location, determine satisfaction level, make migration decision, migrate, earn wages	not described	deterministic

First Author (Year)	Initialisation	Model Steps and Decision Rules	Agent Types: Agent actions	Scenario simulation	Deterministic or stochastic
Fu (2018) (175)	(1) Agents are populated in their rural origin	(1) Network edges are sequentially added between individuals at all levels (family, villages, provinces, and destinations) using the probability of connection (2) Agents decide whether to migrate based on social influences and individual propensity for migration (3) Agents migrate (if they decided to), (4) The network updates to include new migrations	(1) Individual agents: assess migration options, decide whether to migrate, migrate	(1) No social networks, migration decisions are only influenced by the economy and individual attributes, (2) Implicit social network using origin migration prevalence, (3) Explicit social network that includes evolution of social interactions and migration	stochastic: probability of families connecting
Garcia- Diaz (2012) (176)	not described	(1) An Act-share of the total population is enabled to migrate, (2) Every agent in the potential migrants group decides where to migrate based on difference in expected earnings and the agent's social network contacts' locations, (3) The agricultural sector only operates in rural areas and employs all the available rural population (i.e., there is no rural unemployment). The modern and informal sectors only operate in urban areas . Rural residents have no chance of obtaining modern-sector jobs, but once they migrate their chances increase. (4) Employment vacancies are filled first with available preferred individuals who have priority over non-preferred ones.	(1) Migrant Agents: assess past information, assess expected earnings, assess location of neighbours, decide whether to migrate, migrate	not described	stochastic: modern-sector wages

First Author (Year)	Initialisation	Model Steps and Decision Rules	Agent Types: Agent actions	Scenario simulation	Deterministic or stochastic
Hailegiorgis (2018) (177)	(1) 50,000 households are input into the model	(1) Rain falls on land parcels, soil moisture levels are updated (2) After the rainfall update, the vegetation subroutine is executed, by growing or shrinking, depending on moisture available, (3) Households conduct livelihood activities, update profiles, and assess the success or failure of its actions. A household decides whether to adapt in response to anticipated climatic conditions for the season, including the potential to migrate (4) Each household chooses its adaptation strategy by combining herding and farming, in some proportion, depending on what yields the highest return. (5) After the household routine, the herd sequence is invoked	(1) Household Agents: predict rainfall, interact with agents, decide whether to adapt, make migration decisions, allocate resources to livelihood activities, monitor wealth, update memory	(1) Mean annual rainfall with 'normal' onset for the region, (2) Droughts included at various frequencies (every 5, 10, or 15 years), (3) Extreme events in consecutive occurrences at various frequencies (every 5, 10, or 15 years), (4) Erratic climatic conditions incorporating both good and bad years	stochastic: household rainfall predictions
Hassani-Mahmooei (2012) (178)	(1) Initial population of 12,317 Individual-Agents spread across 64 districts	(1) Each agent considers the push and intervening factors and decides on its migration (2) If an agent decides migration is beneficial it then measures the pull factors for all the districts in its 100-km radius and then moves to the closest district with the best socioeconomic conditions in accordance with equation (3) The household size is used to determine natural population growth across the districts	(1) Migrant Agents: perceives social network, makes adaptation decision, makes migration decision, migrates, remembers previous migrations	Various scenarios with increasing trends for climate shock occurrence probability distributed across the districts	stochastic: intervening factor in decision making

First Author (Year)	Initialisation	Model Steps and Decision Rules	Agent Types: Agent actions	Scenario simulation	Deterministic or stochastic
Henry (2017) (179)	(1) User specifies the number of grids and a total number of agents (2) Agents are assigned uniformly at random to grids (3) Series of independent Common Pool Resources (CPRs), populate the model and are set with initial attributes (4) Initial agent behaviour set as cooperative with other agents	(1) Agents make harvesting decisions based on expected payoffs (2) Agents extract from the resource and add to their existing wealth (3) Agents pay their subsistence cost (4) Optionally, discount rates are updated (5) Optionally, migration occurs (6) Each resource grows at the established rate	(1) Individual Agents: assess harvesting payoffs, decide harvesting amount, extract resources, pay costs, migrate	(1) Baseline, (2) Migration is costly, (3) Agents change their discount rates after migration	stochastic: decision on amount to harvest
Ichinose (2013) (180)	(1) Individual agents are randomly distributed over the square lattice. (2) Half of the agents are set to be co-operators and half set to defectors. (3) Population density is set and remains constant throughout a simulation run, since individuals will never die or be born.	(1) Each site is either empty or occupied by one individual. Empty sites represent spatial regions that individuals can migrate to. (2) Agents count the number of defectors in their neighbourhood to decide which distance to migrate to. (3) Agents then migrate to a random cell within the maximum distance they have calculated. If there is no empty site at that distance, then the agent stays in its current location (4) After migrating the agent plays the prisoner's dilemma game with its neighbours and receives any payoffs from the game. (5) After completing the game agents update their cooperate/defect strategy to match whatever strategy received the highest payoff. If there were no individuals in the neighbourhood to play the game with then the agent retains their current strategy.	(1) Individual Agents: count defectors in neighbourhood, decide whether to migrate, decide where to migrate, stay in origin, plays prisoner dilemma game with neighbours, gains payoffs, changes strategy	Various population density scenarios	stochastic: mutations in individual's choices

First Author (Year)	Initialisation	Model Steps and Decision Rules	Agent Types: Agent actions	Scenario simulation	Deterministic or stochastic
Janssen (2010) (181)	(1) Agents are randomly allocated to the landscape (2) Initial agent attribute values are drawn from uniform distributions with a one-third probability of having one of three sharing strategies	(1) Each settlement receives rainfall (2) The individual harvest of agent is defined by the rainfall and the agricultural production quality of a cell (a function of soil quality, population size, and technology) (3) Harvesting: Every agent harvests their chosen amount (randomly selected between sustainable amount and maximum) (4) Sharing: Sharing occurs between agents (5) Exchange: Exchanging of resources between agents selected (6) Migrate: Some agents migrate if they assess their resources are too low (7) After calculating the sharing of food for all agents in all settlements, the model starts calculating the exchange of resources between settlements	(1) Individual Agents: harvest, share, exchange, migrate, consume, store surplus, have offspring, die, network with agents, sense rainfall, evaluates other locations	(1) Baseline, (2) Independent Sharing Mechanism: no sharing among households within a settlement, (3) Pooling Sharing Mechanism: all storage and harvest is pooled each year and distributed equally, (4) Restricted Sharing Mechanism: household surplus is shared with households who have shortage till they meet the minimum requirement	stochastic: rainfall level
Kniventon (2011) (182)	(1) The initial experience rate of an agent is directly retrieved from the dataset on model start-up	(1) Agents can be born, marry or die each time-step and in all time-steps agents age (2) Agents decide whether to migrate (3) The migration decision undertaken by agents only occurs once a year at the end of the wet season in September	(1) Individual Agents: move around environment, interact with agents, interact with environment, develop intentions to migrate, migrate, marry, die, communicate migration decisions with peers, returns home	Varied scenarios of future demographic, economic, social, political, and climate change in a dryland context.	deterministic

First Author (Year)	Initialisation	Model Steps and Decision Rules	Agent Types: Agent actions	Scenario simulation	Deterministic or stochastic
Kniventon (2012) (183)	(1) Population initiate with 4,449 agents	(1) A rainfall condition begins, (2) Individual agents weigh their 5 migration options (3) An agent migrates if it is within their perceived means	(1) Individual Agents: weigh migration options, assess if migration is in their means, migrate	(1) Above-average rainfall, (2) Normal rainfall , (3) Below-average rainfall, (4) No population growth, (5) Low-population-growth, (6) Medium-population-growth, (7) High-population-growth	stochastic: determining perceived means for migration
Mena (2011) (184)	(1) The landscape and social agents are initialised from the survey data. (2) Individuals are put into households and households are assigned farms.	(1) At each time-step there are demographic changes to the population (births, death, marriages) (2) Assets are calculated for each household in each time step. (3) If the household has positive assets, then the household decides any land use changes for the next time period also taking into consideration consumption for that period. (4)If the household has zero or negative assets then a certain number of people on the farm will out-migrate to find work and send remittances home (no land use change occurs)	(1) Individual agents: grows older, gives birth, gets married, dies, interact with landscape, interact with other agents, changes land use type, migrates, sends remittances (2) Household agents: makes all decisions for individual agents, copies neighbours actions	not described	stochastic: migration
Naivinit (2010) (185)	not described	(1) Households decide all Rainfed Lowland Rice-producing activities (2) Rice variety is selected, (3) Establishment of new Rainfed Lowland Rice nurseries and production of seedlings (4) Transplanting and harvesting occur (6) Households update their net incomes and members update their age and migration experiences, (7) Individuals decide whether to migrate (8) Individuals migrate	(1) Household Agents: make RLR decisions, adapt to time constraints, hire farm workers, assess available farm work, interact with other households (2) Individual Agents: decide whether to migrate	(1) Baseline scenario, (2) Various labour availability (e.g., cheap foreign labour), (3) Various water availability (e.g., no water constraint)	deterministic

First Author (Year)	Initialisation	Model Steps and Decision Rules	Agent Types: Agent actions	Scenario simulation	Deterministic or stochastic
Naqvi (2014) (186)	(1) Each owner is endowed with an initial level of fixed capital stock which can produce a maximum output. (2) The initial values are set for the number of agents, maximum daily land production capacity, output self-produced by owners and wage rate	(1) Owners can sell goods in their location, in other locations in the region, or export the surplus based on profit expectations, (2) Workers in each location can stay in their current location or migrate to other locations based on expected income gain. (3) Owners self-produce a fixed level and hire workers for the remaining output in exchange for wages. (4) Workers buy food for immediate consumption and store small amounts for future income shocks	(1) Owner Agents: self-produce goods, hire workers, make profits, pay wages, sell goods locally, export surplus, store, consume (2) Worker Agents: decide whether to migrate, buy food, store food, consume	not described	stochastic: determining the migration destination
Naqvi (2017) (187)	(1) Wage rate is set to a value of USD 0.25 per unit of output per day. (2) The baseline marginal propensity to consume food out of income is set at the higher end of 0.9 out of current income, the marginal propensity to consume non-food goods out of income is fixed at 0.05. (3) The desired number of days, the food inventories are held, is assumed to be 10 days. (4) Initial village and city population levels are set to pre-shock conditions.	(1) The migration and market selling procedures act as stabilizing mechanisms across the region (2) These trade-offs between distance and welfare gains are continuously evaluated by agents in the model. Agents check their earnings, produce goods to earn more or check for more favourable locations to migrate to for a higher real income gain. If real income differences across locations are minimal, workers stay at their current location (3) Agents also check their food consumption each time step to then buy, store, or consume as needed	(1) Individual Agent: consume food, store food, buy food, check destination payoffs, decide whether to migrate, produce goods, sell goods, earn income, location selection	(1) Higher probability of migration, (2) Lower probability of migration	stochastic: location choice

First Author (Year)	Initialisation	Model Steps and Decision Rules	Agent Types: Agent actions	Scenario simulation	Deterministic or stochastic
Raczynski (2018) (188)	(1) Agent's initial attributes and position in the region map are assigned (2) Each region is set with initial job opportunities	(1) Agents have the potential to move in three different ways: random moves, spontaneous migration or migration actions (2) Agents are looking for the region, which maximises the migration criterion. (3) Agents with higher socioeconomic level are more reluctant to migrate (4) Agent can migrate several times and can hold memory of regions they visited in previous migration trips (5) The distance between the regions can also impact the likelihood of migration between regions (6) The length of stay is determined by how long (in average) an entity will stay in the region where the agent has just migrated. If the average is negative or zero then the agent can migrate again immediately, (7) The model includes a gregarious effect (herd instinct) whereby people are influenced by their peers	(1) Individual Agents: random move, spontaneous migration, decided whether to migrate, migrate, re-migrate, store migration memories	(1) With gregarious (herd) effect, (2) Without gregarious (herd) effect	stochastic: agent random-move action
Silveira (2006) (189)	(1) All workers are randomly distributed in the lattice (2) 20% of the population is urban.	(1) A set probability of worker review their sectorial location and become potential migrants in each time step (2) All potential migrants make the migration decision based on expected wage differentials between their present sector and future (3) As soon as the potential migrants end their reviewing process, a new sectoral distribution is obtained.	(1) Worker Agents: paid wages, decide whether to migrate, migrate	(1) Agent decisions are guided by deterministic private utility (expected urban-rural wage difference), (2) Agent decisions are guided by the deterministic private utility and the social private utility, (3) Agent decisions are guided only by the social private utility	stochastic: job placement and utility function

First Author (Year)	Initialisation	Model Steps and Decision Rules	Agent Types: Agent actions	Scenario simulation	Deterministic or stochastic
Simon (2019) (190)	(1) Agents are assigned to a site on the square lattice	(1) Agents originate from a single location and can migrate to one of two destinations. (2) Migrants weigh destination choice based on network benefits and expected wages (3) Having chosen their destination, agents at the origin will migrate if their accumulated wealth in the current year is larger than or equal to the cost of migration (4) Migrants evaluate policy conditions and their probability of attaining a visa, (5) Migrants attempt migration (6) Once abroad, all agents spend their yearly wages, on food and lodging (consumption). They may also send remittances. (7) All agents have an equal chance of re-migrating.	(1) Individual Agents: decide whether to migrate, migrate, decide whether to return home, return home, attain visa, earn wages, spend wages, consume, send remittances, re-migrate	(1) Random networks, (2) Regular networks	stochastic: assigned networks
Smith (2014) (191)	not described	(1) Individuals make the migration decision and the decision is mediated by the household's ability to finance the migration (2) Household resilience is determined by income and food production each month (3) For a household to accept farm labouring opportunities, they must be made available by another household within the simulation (4) For a household to be able to invest in migration, the surplus remaining each month following subsistence must be greater than the cost of opportunistic migration (5) Household determine their willingness to send migrants	(1) Individual Agents: decide whether to migrate, migrate (2) Household Agents: determine if they can finance migration, accept farm labouring work, offer farm labouring work	(1) Baseline weather, (2) Dry weather, (3) Wet weather, (4) Extra dry weather, (5) Extra wet weather	deterministic

First Author (Year)	Initialisation	Model Steps and Decision Rules	Agent Types: Agent actions	Scenario simulation	Deterministic or stochastic
Suleimenova (2017) (192)	(1) GIS mapped environment and migration routes are set up. (2) Initial sets of refugees are placed in conflict locations.	(1) New refugees are inserted into their location of origin (a conflict location) (2) Agents travel a certain number of links (0+) each based on their move-chance (probability to migrate). In traversing between locations, refugees take major roads, which are shortest journey paths identified using route planners. (3) If a refugee reaches the end of a link but has travelled less than 200 km on that day (i.e., one time step), then a new move-chance calculation (and possible move) is performed. (4) At varied time-points borders might close and refugees might need to re-route.	Refugees Agents: decide whether to migrate, decide where to migrate, migrate	(1) Burundi conflict, (2) CAR conflict, (3) Mali conflict	stochastic: probability of migration
Tabata (2003) & (2004)* (193, 194)	(1) Agents are randomly assigned to domain sections	(1) At each time-step agents consider migration, (2) Agents either migrate or stay in their current location based on utility calculations, (3) Each agent chooses one section at random at each time-step and compares the utility of the chosen section with the sum of the utility of its current section, the cost of migration and a named constant (representing the cost incurred in deciding whether or not to relocate within each time interval) to decide whether or not to relocate within the time interval, (4) If an agent moves from one section to another, then it needs to bear the cost of moving in a real world, (5) The population density is updated.	(1) Individual Agents: decide whether to migrate, pays cost of migration, and their destination	2003: (1) Agents take only the present behaviour of agents into account, there is a fixed number of agents, (2) Agents relocate based on considerations of agents' future movements, there is no limit on the number of agents 2004: (1) Utility is defined as an increasing affine function of the density of agents, (2) Utility is equal to a concave quadratic function of the density of agents	stochastic: utility of migration

First Author (Year)	Initialisation	Model Steps and Decision Rules	Agent Types: Agent actions	Scenario simulation	Deterministic or stochastic
Walsh (2013) (195)	(1) Creation of social agents, land objects, and characteristics such as population migration, crop yield levels, and landscape settings	(1) At each time-step there are demographic changes to the population (births, death, marriages) (2) Assets are calculated for each household in each time step to determine land use, land use changes, moves to other nearby farm or migration. (3) Households can interact with other households to learn from their farming actions. (4)If the household has zero or negative assets then a certain number of people on the farm will out-migrate to find work and send remittances home	(1) Household Agents: change land-use, move farms, send migrants	(1-9) Different monsoon scenarios	stochastic: migration
Wu (2011) (196)	(1) All cells are initialised in null state (2) 60 million individuals are assigned to 31 provinces using historical data	(1) Cells collect environmental information to update their states (2) The choice to migrate is influenced by larger macro elements of climate change, potential agricultural productivity change, and waves of mass migrations (3) Individual agents who decided to move out of a unit choose their destination province by roulette wheel arithmetic based on the attraction between the other provinces (4) After migrating, agents select an inner cell (residential unit) randomly within the destination province and check whether the target cell is suitable for living and has capacity, if not then the agent continues to float and chooses a new target in the province. (5) Cellular and provincial data are updated after agents migrate.	(1) Individual Agents: decide whether to migrate, migrate, choose destination province, selects province cell, assess cell suitability and capacity, floats, settles in cell	(1) No external disturbances occur, (2) Climate change occurs, (3) Climate change and the Yongjia Migration occurs, (4) Climate change, the Yongjia Migration, and the Anshi Migration occurs, (5) Climate change, the Yongjia Migration, the Anshi Migration, and the Jingkang Migration occurs, (6-9) Only one of the 4 migrations is considered: Yongjia, Anshi, Jingkang, or HuGuang	stochastic: cell destination
*The models presented in Tabata's 2003, and 2004 papers are identical by most of the points extracted for this review. The differences in the models have been captured in the 'Scenarios' column					

Table 12 also indicates whether the ABM is deterministic (n=6) or stochastic (n=22), stochastic means that it includes some element of randomness (through specifying probability distributions) in determining agent actions, social network composition, or some element other than the initialization settings. One example of the inclusion of a stochastic process can be found in the Entwisle et. al. model where an individual agent's propensity to migrate is compared to a randomly drawn number and if their propensity to migrate is higher than that number then they migrate (173). Uncertainty in decision-making is pertinent to low-wage labour migration where the migration planning can be unsystematic, and the outcomes not guaranteed. Introducing some randomness in decision-making and the migration process reflects some of this uncertainty in outcome. This approach can also model that there is the possibility of divergence from expected decision-making behaviours in some cases due either to natural variability in behaviours or uncertainty, which is an acknowledgement that we might not be aware of all the heterogeneous agents' considerations.

5. Model analysis

Finally, we reviewed the main output variables in the analysis of the models, whether the authors conducted uncertainty or sensitivity analysis (according to the authors), and if and how the model was validated, again, in the authors' own words (Table 13). We also extracted the model assumptions and study limitations as described by the authors (Appendix 4.3).

In relation to sensitivity or uncertainty of outcome variables, most of the studies (n=25) looked at least at one migration indicator (migration rates, population distribution, urban vs rural population shares, etc.). Only one study looked at health-related outcomes (170). Only one study looked at slavery as an outcome (172). Ten studies looked at some outcome measurement related to financial or resource utility gain (expected earnings, household assets, crop yields, savings, etc.). Only two studies looked at

outcomes related to social network structure (such as network dependence and spatial effects of social influence).

In total, ten studies mentioned some sort of sensitivity testing. Most of these detailed variation testing for a select number of key variables, two studies described using a probability distribution functions of key parameters approach to testing key variables (170, 196). When assessing whether the models were validated, we relied on the authors' accounts of analysis intended as a form of validation analysis. Twelve studies mentioned some form of model validation (Table 13). Validation is a challenging task when there is a scarcity of reliable or comparable real-world data. Anderson et. al. and Entwisle et. al. compared their model outputs with research on a similar topic but using different methods, logistic regression and a system dynamics model respectively (170, 173). Three articles, Fu and Hao, Hassani-Mahmooei and Parris, and Wu et. al. all compared the output of their models to available census or population data and Naqvi also compared model outputs to a relevant secondary dataset (175, 178, 196). Chesney et. al. considered validation of the model to be a thorough comparison of whether the model outputs captured the key principles of the Crane's theory on slavery as a management practice (172). In both Kniventon et. al. studies, the model outputs were compared to the *Enquête Migration, Insertion Urbaine et Environnement au Burkina Faso* (EMIUB) dataset, which was the same dataset used for calibration of the models (182, 183). Naivinit et. al. was the only paper that described using stakeholder validation techniques by having key experts review and critique to model (185). Raczynski struggled to find any available data for validation so instead showed how the model output trends compared to migration flows in three other contexts (188). Suleimenova et. al. used the United Nations High Commissioner for Refugees (UNHCR) refugee camp registration dataset as one comparison point, but then also used the Mean Absolute Scaled Error (MASE) to compare the model outputs to six other model techniques (192). Again, it

was not within the scope of this review to assess the quality of any aspect of the ABM models, so we have not provided quality assessment of the sensitivity analysis, uncertainty analysis or validation methods reported by the authors of these studies.

Table 13. Model analysis

First Author (Year)	Output variables	Uncertainty and sensitivity analysis as described by the author(s)	Model validation as described by the author(s)
Alghais (2018) (169)	population distribution, internal migration patterns, new city development stages, nationality segregation levels	not described	not described
Anderson (2007) (170)	health indicators, number of refugees receiving medical treatment	Levels of food and water were varied while the other four parameters were held constant at their midpoints. Additional runs were performed for each of the other four input variables.	Internal model validity was assessed by verifying that its data, variables, and parameters are based on experimentally developed theories such as well-being and data from the UN Refugee Agency. Outcome validity was assessed, predictions from the agent-based model were compared with the predictions from an independent system dynamics model on the same topic.
Cai (2015) (171)	distribution of workers	not described	not described
Chesney (2019) (172)	contract slavery (paid less than minimum wage), diffusion of slavery	not described	The model was validated by examining how well it captures Crane's theory on modern slavery as a management practice.
Entwisle (2016) (173)	rates of in-migration, rates of out-migration	not described	Some analytical comparison to a regression-based prediction of the effect of climate change on migration as a counterpoint with which to compare the ABM results. A scenario with the actual recorded weather conditions from 1975 to 2000 was also included. This scenario's results were substantially equivalent to those for the reference scenario.
Espındola (2006) (174)	urban share, urban unemployment rate, rural-urban expected wage differential	not described	not described
Fu (2018) (175)	social network structure, migration rates, interdependence of network and migration outcomes	The model incorporates uncertainty of parameters by using distributions of parameters.	Network changes were validated by comparing the migrant share with the cumulative causation theory of migration that highlights the influence of migrants on non migrants' future moves. Migrant behaviour was validated by comparing the model outputs against the aggregate data from the census.
Garcia- Diaz (2012) (176)	worker distribution, spatial effect of social influence, expected wages	Individuals' sensitivity to utility variations was tested.	not described

First Author (Year)	Output variables	Uncertainty and sensitivity analysis as described by the author(s)	Model validation as described by the author(s)
Hailegiorgis (2018) (177)	population size, migration rates, livestock and crop production, household wealth	not described	not described
Hassani-Mahmooei (2012) (178)	migratory paths, population distribution	not described	The model population projections were validated by comparison with published primary results of the Bangladesh 2011 Population and Housing Census.
Henry (2017) (179)	harvesting rates, resource sharing, migration	not described	not described
Ichinose (2013) (180)	cooperation, defecting, migration	Sensitivity analysis of the result was conducted over varying mutation rate.	not described
Janssen (2010) (181)	population size and density, average resource level, agent strategies, strategy evolution	Sensitivity analysis was conducted on the main parameters of the model by varying parameters from relatively low to high.	not described
Kniventon (2011) (182)	migration flows	not described	A five-run-averaged total migration flows are compared directly with the observed EMIUB record.
Kniventon (2012) (183)	migration flows	not described	The observed flow of migrants in and from Burkina Faso, as recorded by the EMIUB retrospective multilevel migration history survey is shown alongside modelled migration flows from an ABM for the period 19701994.
Mena (2011) (184)	mean assets, land-use, migration rates	not described	not described
Naivinit (2010) (185)	household income, number of migrants	not described	One early form of validation was collaborative design of the ABM with local farmers, (2) Expert validation: The BMM model has been recognised by the participating farmers as a sufficiently accurate representation of their current situation. These farmers were confident enough in the model's form to be able to articulate it and present it in academic settings to researchers.
Naqvi (2014) (186)	number of workers, rural population, worker, food price, daily income, income savings, food consumption	To assess the sensitivity of the model to various shock levels, we perform multiple simulation runs for food production shocks ranging from 50 to 75% in steps of 5%. Sensitivity bands are generated from 10 simulation runs per shock.	not described

First Author (Year)	Output variables	Uncertainty and sensitivity analysis as described by the author(s)	Model validation as described by the author(s)
Naqvi (2017) (187)	income, food price, savings rate, percentage starving, income/ consumption distribution, displacement, dispersion	The model is tested for parameter sensitivity for pre-shock outcomes and loss function sensitivity for post-shock outcomes	Initial pre-shock conditions are validated through comparison with available secondary datasets, but this could not be done for the post-shock model data.
Raczynski (2018) (188)	migration flows	not described	Validation was acknowledged as a limitation. The authors made comparisons to similar migration flows in Australia, New Zealand and Bangladesh.
Silveira (2006) (189)	distribution of urban/rural workers, expected wages ratio	not described	not described
Simon (2019) (190)	migration flows, destinations, length of migration, number of migrations	Sensitivity tests were conducted by varying parameters, such as number of ties at home and utility for return. Sensitivity testing was also conducted for the sample size and some of the model assumptions.	not described
Smith (2014) (191)	migration flows, household resilience	The probability function approach was used to explore the sensitivity of the modelled system to changes in the shape (non-scaled normal or sigmoid) and scale (point at which optimal yield is achieved) of the relationship between rainfall, livelihood/food security and migration.	not described
Suleimenova (2017) (192)	total refugees, refugee dispersal	Sensitivity tests were completed for the move-chance variable, conflict locations, attractiveness value for camps, and conflict zones.	The average relative differences are presented between the ABM prediction results and the UNHCR refugee camp registration data. The results were also compared to the Mean Absolute Scaled Error (MASE) using six other techniques.
Tabata (2003) & (2004)* (193, 194)	migration	not described	not described
Walsh (2013) (195)	crop yields, migration, household assets	not described	not described
Wu (2011) (196)	agent relocations	not described	To test the validity the Scenario 1 simulated population of each province is compared with the corresponding real provincial population as of 2003 to see if the model results replicate historical trends of population in China.
*The models presented in Tabata's 2003, and 2004 papers are identical by most of the points extracted for this review.			

6. Correlations between model aim and model development choices

Similar to Klabunde and Willeken's review and Thober and colleagues' review (134, 136), this review presents a range of unique models in examining both the model aims and model development processes. Due to the lack in standardised reporting of the model development, it is not straightforward to make conclusions about correlations between model aims and model development choices. That said, Table 14 presents a summary of some critical model development choices that we believe relate to the model's purpose. We have grouped the included publications according to their original study aim categorisation (Table 9) and presented model characteristics that span model calibration, development and process (Tables 10-12). While we again acknowledge that some of the reporting on model development choices was opaque, from the descriptions we were able to extract, we have observed a few correlations between study aims and model development choices.

Most ABMs exploring environmental-migration links and humanitarian migration used empirical data, this might reflect the highly context specific nature of research questions on these topics which require in-depth up-to-date familiarity with the regions, geographies, and events pertinent to the real-world questions. Context specific models on the influence of climate change or humanitarian crisis require empirical embeddedness and would be limited in their claims if they relied only on theory to calibrate models. Likewise, most of the environmental-migration ABMs mapped real geographic environments where these environmental-migration related phenomena are emerging. While the same importance to context-specific data relates to models investigating modern slavery trends of the social dynamics of migration, there are fewer examples of empirically embedded models, which is more likely to reflect data scarcity in these fields and not a correlation to study aim. Most of the models exploring socially influenced migration patterns used abstract representations of space which is usually a

sufficient simplification of this type of model since the question of interest is social spaces and linkages and is not necessarily concerned with how the abstract representation maps to real geographic space. The models in this review use a range of representations of time-steps. Notable correlations we observed were that the humanitarian migration models use shorter representations (hourly, daily) across all the 4 models which likely reflects the acute timelines of humanitarian crises and the aim to understand large-scale human mobility patterns in short time frames. In comparison, the ABMs aiming to explore migration demographic and regional trends more frequently used annual time-step representations to explore human mobility over longer more regular intervals.

In relation to the inclusion of dynamic interactions, it appears that models that aimed to present environmentally motivated migration all include agent-to-environment interactions, likewise models looking at socially influenced migration all include social networks and agent-to-agent interaction. In comparison, fewer of the models on migration demographic or regional trends include these dynamic interactions. Finally, we thought it was pertinent to note that across all the study aim categorisations there was frequent use of model scenario testing. This is not entirely surprising as this is a key feature and advantage to ABM methods, but it is a particularly useful approach to use on research topics that include high degrees of uncertainty often due to data scarcity or rapid adaptations in individual behaviour and population trends, which are both true of research on human migration influenced by many dynamic factors, such as changing environments, acute crises, and evolving social networks.

Table 14. Summary of model aim and model development

Broad research category	Data Sources		Agent Types	Spatial-Temporal & Networks			Dynamic Interactions		Scenarios
First Author (Year)	Empirical	Theory	2+	Space	Social Network	Time-steps	Agent-Agent	Agent-Enviro.	2+
Economic migration									
Henry (2017) (179)	×	✓	×	abstract	✓	time-to-event	×	✓	✓
Environmental migration									
Entwisle (2016) (173)	✓	✓	✓	real	✓	annually	✓	✓	✓
Hailegiorgis (2018) (177)	✓	✓	×	real	×	daily	✓	✓	✓
Hassani- Mahmooei (2012) (178)	✓	✓	×	real	✓	monthly	✓	✓	✓
Janssen (2010) (181)	×	✓	×	abstract	✓	annually	✓	✓	✓
Kniventon (2011) (182)	✓	✓	×	real	✓	daily	✓	✓	✓
Kniventon (2012) (183)	✓	✓	×	real	✓	annually	×	✓	✓
Mena (2011) (184)	✓	×	×	real	✓	annually	✓	✓	×
Naivinit (2010) (185)	✓	×	✓	artificial construct	✓	daily	✓	✓	✓
Smith (2014) (191)	✓	✓	✓	missing	✓	monthly	✓	✓	✓
Wu (2011) (196)	✓	×	×	real	✓	annually	✓	✓	✓
Humanitarian migration									
Anderson (2007) (170)	✓	×	✓	artificial construct	✓	hourly	✓	✓	×
Naqvi (2014) (186)	✓	✓	✓	artificial construct	✓	daily	✓	✓	×
Naqvi (2017) (187)	✓	✓	×	abstract	×	daily	×	✓	✓
Suleimenova (2017) (192)	×	×	×	real	×	daily	×	✓	✓
Alghais (2018) (169)	✓	×	✓	real	✓	annually	✓	✓	✓
Cai (2015) (171)	×	✓	×	abstract	✓	daily	×	✓	×
Silveira (2006) (189)	×	✓	×	abstract	✓	missing	×	×	✓
Simon (2019) (190)	✓	✓	×	abstract	✓	annually	✓	✓	✓
Wu (2011) [73]	✓	×	×	abstract	×	annually	×	✓	✓
Espındola (2006) (174)	×	✓	×	abstract	×	time-to-event	×	×	×

Tabata (2003) & (2004)* (193, 194)	×	✓	×	abstract	×	missing	×	×	✓
Modern slavery									
Chesney (2019) (172)	×	✓	✓	abstract	✓	daily	✓	×	✓
Social migration									
Fu (2018) (175)	✓	✓	×	abstract	✓	monthly	✓	×	✓
Garcia- Diaz (2012) (176)	×	✓	×	abstract	✓	time-to-event	✓	✓	×
Ichinose (2013) (180)	×	✓	×	abstract	✓	time-to-event	✓	✓	✓
Raczynski (2018) (188)	×	✓	×	artificial construct	✓	daily	✓	✓	✓

Limitations

This review does not include structured quality assessments with comparable quality scores. Again, this was partly because the aim of this review was to learn from the methodological approaches not to assess the research findings and the rigor of the findings. As explained in the beginning of the results, models like agent-based models but called by different names were excluded for the sake of reproducibility of this review and uniformity in data extraction. We acknowledge that this inclusion criteria may have excluded valuable studies to meet this review's objective and may have introduced a disciplinary bias to this review's inclusion and therefore results. To account for this potential loss, we have included these 8 studies in a table in the Appendix 4.2 for any reader that might be interested to review this specific subset of excluded studies and compare the model development with those included in this review.

This review also did not include some potentially relevant models that have not yet been peer-reviewed but are available on multiple sharing platforms (such as, OpenABM, GitHub, NetLogo libraries). Finally, the large variability in model characteristics makes in-depth synthesis and comparisons of all data extraction points a challenging task. We have attempted and hopefully succeeded at giving a bird's eye overview of the data extraction while not oversimplifying the nature of each model by comparing the various elements of the ODD+D framework too broadly.

Discussion

State of the art in ABM in migration and modern slavery research

The aim and contribution of this review has been to summarise the use of ABM for migration and modern slavery research to present researchers and decision-makers with a comprehensive overview of how ABMs on migration have been developed to date, as well as identifying gaps in ABM development and use in the field. This review highlights that ABM is a method increasingly used in migration research as it has been in other social and health science research topics. To date, ABMs in this field have been used primarily to test theories and less frequently draw on primary empirical input. The main theories modelled in the ABMs identified in this review were utility maximisation theory, social network theory and theory of planned behaviour. Across all the ABMs, about half were neither based on empirical data nor on clearly defined behavioural theories. This is very likely a reflection of the scarcity of empirical data and theoretical frameworks on migration that take a complexity science approach. Many scholars working on social ecological modelling have noted this as an issue across ABMs in many disciplines (133).

The ABMs described in this paper commonly recognised the role of social networks in migration, but few used advanced methods of social network analysis to inform the dynamics of network evolution over time and space. We agree with Klabunde and Willken's assessment that there is still a lot of work to be done in integrating network analysis techniques into ABMs (134). The papers in this review also noted the complexities in the migration decision and processes. However, with the exception of Suleimenova (2017) (192), most models assumed that migrants were 'rational agents', for example that migrants knew the target labour markets at destination, that the choice of destination was open and informed, and that deception was not a possibility. Many of these models did not capture all of the core elements of decision-making, notably missing are the evaluation of

migration options or complexity in the decision process that Klabunde and Willeken's emphasised in their review (134). For instance, going back to our earlier example of research on the nexus of low-wage labour migration and modern slavery, none of the labour migration models in this review included the risks of labour exploitation and how this might influence migration decision-making or expected utility calculations. In that respect, these models do not capture the experiences of most low-wage labour migrants globally. The challenge is that there is a knowledge gap on how the risks of labour exploitation or other forms of modern slavery might influence individual behaviours. There are many areas we still do not understand the underpinning mechanisms of entry into modern slavery versus decent work and thus the models trying to represent low-wage labour migration are not transferable to real-world interventions. The choice of stochastic models may compensate to some extent for these knowledge gaps or further unknown heterogeneity in migration behaviours and outcomes. However, it is also important to note that some uncertainty cannot be reduced by acquiring knowledge, such as variability in agents' behaviours. Thus, the stochastic variability will always be essential to account for some of these irreducible uncertainties. However, the consideration of decision-model options and choice is a critical step in ensuring models capture the complexity of real-world processes. Klabunde and Willeken's review provides in-depth recommendations on the way forward to capturing migration decision-models in ABMs (134). Scholars exploring the intersection of cognition and multi-agent systems have emphasised opportunities to integrate cognitive modelling into social studies addressing complex behaviours that originate in individual perceptions (203).

Additionally, the models' development varied considerably in terms of attributes and interactions of agents, time, space, and environment. The most common model processes involve scenarios where an agent decides whether to migrate, where to migrate to, and then attempts to execute the

act of migration. Changes in scenarios were introduced in ABMs by changing exogenous elements or altering decision rules, but the majority of these were climate scenarios and these models would benefit from a broader exploration of influences on individual migration behaviours as Bell and colleagues also recommend in their recent review (135).

Finally, many of the ABMs did not undergo validation or sensitivity analysis, which are critical steps to ensuring rigor in ABM methods and confidence in their use to inform policy makers. Model validation is an area of work critical to all ABM practice and methods of empirical validation are still in their infancy as are standardised best practice of model analysis (133, 204). While there are serious challenges to validating ABMs modelling in data-scarce topics such as this, there are nonetheless validation methods that are feasible and acceptable given these challenges (153, 205). The major challenge concerns validating the ABM against qualitative data in part because much of this data has not been collected with developing ABMs in mind and it can be difficult to calibrate or validate the decision-rules from these data sources. There is an opportunity for methodological development in translating qualitative analysis for use in ABMs. Even small samples of key expert interviews can be critical in informing the model development and justifying the model design (199).

Future considerations for migration ABMs

Migration complexity research will benefit from studies that collect primary data on migration and migration outcomes, such as modern slavery, with ABMs in mind from the research design conception stage. Going back to our migration and modern slavery example, researchers can collect information specifically about the agents (migrants, brokers, intermediaries, employers), agent-attributes (migration experiences, migration knowledge, resources to migrate), agent-agent interactions (who influences migrants' attitudes toward migration, how migrants meet brokers, how migrants find or change

employers at destination), agent-environment interactions (how migrants engage with or avoid institutions managing legal labour migration pathways), and most importantly, how individuals and groups make decisions, learn and adapt (the emergence of preferred migration pathways over time). A further benefit of ABM methods and future consideration in study design is that multiple data sources can be incorporated from several disciplines. This review presents examples of how ABMs can use multiple data sources, but one method that has been under-utilised in this group of studies is participatory methods with key stakeholder groups and the target population of interest, which have offered critical insights to other nascent fields of computational social science research. For example, the stakeholder approach allows modellers with perhaps in-depth theoretical knowledge on the topic to collaborate with domain experts and triangulate these sources of established theory and current expert knowledge (199). There was one example in this review that used this stakeholder approach in a series of workshops with Thai farmers to inform the individual behavioural rules of the model to reflect the Thai context. An interdisciplinary approach is critical to be able to integrate theoretical and empirical knowledge of a social phenomenon into a mathematical model (146). In fact, we concur with the other reviews, future ABM work in this area would benefit from interdisciplinary approaches to every stage of model development in order to address research questions that cut across social and ecological studies, as well as disciplines such as economics, psychology, geography and complexity science (134, 136). Diverse disciplinary and theoretical perspectives will strengthen the real-world likeness of these highly complex, dynamic and socially embedded models and may present new uses for existing data for model calibration.

Lastly, despite widely accepted challenges and shortcomings to standardising model analysis procedures and model validation, all future ABM studies must critically consider their approaches to these steps, learn

from ABM practices across all disciplines and document the justifications for their analysis and validation choices as well as their process to enable a wider and more synchronised debate on future best practice.

The need for transparent and clear reporting on model development

The model descriptions in the articles included in this review were overwhelmingly opaque with various critical details omitted. This review is not the first to critique the lack of a 'best practice' in reporting model development (133, 136) and as one reviewer noted there are severe limitations to systematic reviews that aim to synthesise findings across a body of studies whose methods cannot be easily compared, not to mention that there is still work to be done to develop standard methods for systematically reviewing ABMs (158).

In this review, there was generally insufficient detail or models were reported without proper sign-posting or terminology that could be understood by most readers. Since few of the studies used recommended development frameworks, such as ODD+D, there was not a structure or fluidity to the way the model choices were reported, which makes it difficult to interpret findings and learn from the methods at a critical stage in methodological development for the field of migration and modern slavery research. This critique is true for ABM research on other topics as well. This review suggests that more frequent use of the ODD+D framework will strengthen future ABM research

In addition, the methods of sensitivity analysis and model validation were described in limited detail or not covered by the authors, which leads us to assume that the analysis was either not done or not completed. The findings of the models arguably are then open to substantial criticism regarding their validity and applied usefulness. This weakness is a critical gap in the evidence base since the topics of migration and modern slavery are priorities on many global agendas, including the beforementioned Sustainable Development Goals (9).

Using ABM to address pressing and complex questions in the fields of migration and modern slavery research

Migration is currently a focus of substantial international attention, particularly global economic migration and modern forms of slavery. Policy-makers are seeking a strong evidence-base that can be used to address the myriad aspects of global mobility. Current pressing concerns include migration patterns and trajectories, individual or group vulnerability, and migrant protection and safety. To date, robust evidence to inform policy-making has proven to be weak because individual and population mobility cannot be explained by the exclusive use of methods that assume linear average effects of exposures on single outcomes affecting homogenous populations. The patterns of migration and characteristics of migrants are emergent consequences of many interacting and non-linear, unpredictable phenomena - this complexity requires an agent paradigm approach (140).

For example, many of the current interventions and policy goals for safer migration are currently relying on extremely simplistic cause and effect assumptions about the exposures that might lead to modern slavery. If we are going to achieve SDG 8.7— "eradicate forced labour, end modern slavery and human trafficking and secure the prohibition and elimination of the worst forms of child labour, including recruitment and use of child soldiers"—we must engage with the complexity and dynamics of low-wage labour migration and population-level emergent outcomes (such as widespread labour exploitation) in our research methodologies (9). For example, the influence of social networks in group decision-making must be explored in greater depth and this will give rise to a greater understanding of how these interactions might hinder the effectiveness of migration interventions that operate on the individual level (60).

To study migration, one must go beyond simple binaries, such as: domestic or international; documented or undocumented; recruiter facilitated or social network facilitated; forced or voluntary; for asylum or for work, etc.

Because migration is a mechanistic and dynamic process, analyses must be able to address this complexity.

Agent-based modelling offers a promising method to improve our understanding of and programmatic responses to these real-world problems. This review offers an overview on how ABM has been used in the fields of migration and modern slavery research and the remaining gaps and potential future uses to advance the application of these methods to inform more effective responses to high-risk migration and modern slavery.

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RESEARCH PAPER COVER SHEET

SECTION A – Student Details

Student ID Number	388074	**Title**	Miss
First Name(s)	Alys Mary		
Surname Name	McAlpine		
Thesis Title	Mediated labour migration in the Myanmar-Thailand corridor and precarious outcomes: a mixed methods social network analysis and agent-based model		
Primary Supervisor	Cathy Zimmerman		

SECTION B – Paper already published

Where was the work published?			
When was the work published?			
If the work was published prior to registration for your research degree, give a brief rationale for its inclusion			
Have you retained the copyright for the work?*		Was the work subject to academic peer review?	

SECTION C – Prepared for publication, but not yet published

Where is the work intended to be published?	Journal of Mixed Methods Research
Please list the paper's authors in the intended authorship order:	Alys McAlpine, Luke Demarest, Cathy Zimmerman, Ligia Kiss
Stage of publication	**Submitted**

SECTION D – Multi-authored work

For multi-authored work, give full details of your role in the research included in the paper and in the preparation of the paper.	I led the study design, tool design and piloting, fieldwork, data cleaning, data analysis, and authored the first draft of this paper.

SECTION E

Student Signature	[redacted]
Date	27-06-2021

Supervisor Signature	[redacted]
Date	27-06-2021

4.2 Mixed Methods Research Note

4.2.1 Preamble to Paper 2

Informed by the systematic review and the literature on ABM methods for social simulations, the empirical data collection aimed to collect a 'complex dataset' that could inform the various elements of a complex labour migration system simulation – the ABM. Historically, ABMs have most often been informed by theory or subject knowledge, sometimes in the form of 'toy-models' for further theory development. More recently, the field is advocating for more empirically-based ABMs with applied research aims. Recent use of ABM for Covid-19 research has been a testimony to that shift (206–208), but to date, most ABMs have been informed by quantitative datasets, and only rarely by qualitative or mixed methods datasets. The range of entities, behaviours, and processes included in a single ABM are unlikely to be captured by a single type of data or analysis.

This second paper focuses on the methodological features of a mixed methods complex system study design and the contributions this approach makes to the fields of mixed methods research and empirically-based ABM methods. This methods paper focuses specifically on the choice of methods, integration of methods, and, most extensively, the role of the study tools in facilitating the mixed methods design. This paper is the corresponding methods piece to the empirical mixed methods social network analysis results paper presented in the following paper of this chapter (Paper 3).

This paper has been submitted as a 'Research Note' to the *Journal of Mixed Methods Research,* which entails writing a brief (3,500 word maximum) description of a new methodological contribution to the field of mixed methods research.

4.2.2 Paper 2

Visual network tools for mixed methods complex systems research: lessons from a study with migrants

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Keywords: mixed methods, egocentric network, visualisations, participatory, complex system

Acknowledgements: AM led the study design, tool design and piloting, fieldwork, data cleaning, and data analysis as part of her Doctoral thesis; LD led on the software development and data visualisation and contributed to the design, piloting, and iterative development of the tools during fieldwork; LK and CZ supervised and advised the study design; AM wrote the first draft of this paper; and all authors revised and contributed to the final draft.

Abstract

Combining mixed methods and complexity science presents a promising area for methodological development for social science research. These complementing fields of research have theoretical frameworks and technical tools to help address the challenging complexities of real-world problems. However, to date, developments at this methodological nexus have been primarily in the form of conceptual clarifications and methodological commentaries, while there remain few examples of innovative tools or techniques applied in empirical research designs in Public Health and other social sciences. To begin to fill this gap, this paper presents a case study of a complex system study design that incorporates mixed methods social network analysis and agent-based modelling. Together these methods were able to capture and explore multi-level and complex datasets. To facilitate this study design, we built two separate visual network tools for the data collection and analysis stages of the research. This paper presents the tools, lessons from implementation, and reflections on the overall study design.

Introduction

Mixed methods researchers are exploring better ways to harness complexity theory and methods to study and theorise complex systems (209). They argue that complexity theory underpins mixed methods paradigms and that in return, mixed methods strategies, offer a pragmatic approach to complexity science (209, 210).

Increasingly, complex systems frameworks are being used to understand 'causal mechanisms' for various large-scale problems, such as armed conflicts (211), racial inequalities in health (212), and food insecurity (213). Despite significant uptake of complex systems *thinking*, these complex systems frameworks rarely evolve into advanced methods of complex systems analysis. Addressing this lag between the adoption of complexity theory and application of methods is an essential step toward integrating complex systems approaches into intervention design and evaluation (13).

Complex systems are composed of many parts that interact at multiple -levels (micro-meso-macro), which suggests the need for mixed methods approaches that cut across disciplines and address different levels of analysis (210). Research design choices are influenced by aims, epistemologies, and a range of practicalities, but also by published designs that can be referenced (210). This bias towards published work may help explain why we are experiencing an 'early adoption' lag between theory and methods. Professor of Complex Systems, Dr Liz Varga, argues that, "Complex systems research on the real world requires experimentation of alternative methods and techniques which do not reinforce existing choices and which encourage innovative thinking." (210) Similarly, complex systems researchers, Miller and Page, call for "sustained and imaginative effort" to endeavour to integrate complex systems thinking into research design (104). The nascent field of mixed methods complexity science (or 'complex mixed methods') presents an exciting landscape for methodological innovation, which is propitious for applied social science research on complex problems.

Introducing a mixed methods complex system case study

This paper presents a mixed methods complex system study that integrated two 'complexity-congruent methods': social network analysis (SNA) and agent-based modelling (ABM) (13, 142, 209). The latter is a method for complex system simulation. To our knowledge, there are currently no papers on ABM methods published in major mixed methods journals and, likewise, there are few examples of mixed methods approaches informing empirical systems modelling in systems research (209, 214). Complex systems modellers, like mixed methods researchers, contend that new ontologies, methods, and tools are needed to integrate different qualitative and quantitative data sources into empirical modelling (214).

This case study contributes to the current methodological gap in 'mixed methods complex systems' approaches by presenting a study design that integrated multiple complex systems methods using mixed data sources and by using newly conceptualised tools.

Empirical aim

For context, the study's empirical aim was to explore migration networks and pathways as mechanisms for migration outcomes. Interviews were conducted with Myanmar migrants working in low-wage sectors (e.g., manufacturing, fishing) in popular destination and border areas in Thailand. The remote study sites and hard-to-reach sample provided unique lessons about challenging fieldwork settings, which are woven throughout this paper.

Case study aim and audience

This paper focuses on the custom-built visual network tools that facilitated an empirical *mixed methods* SNA (MMSNA) study, which was purposely designed to inform an ABM. The aim of this paper is not to present study results (215) nor advocate for the wider use of these *specific* tools. This paper aims to advance mixed methods complex systems research by presenting a methodological case study that includes the MMSNA tools,

lessons from implementation, and reflections on the suitability and feasibility of using MMSNA to inform an ABM.

This paper is written for social scientists, particularly mixed methods researchers who consider applying complex systems or network methods, and for complex systems modellers contemplating new methods to inform empirical modelling.

Visual network tools for MMSNA

For this study, we designed two visual network tools to facilitate convergent mixed methods social networks data *collection* and *analysis*. 'Convergent' meaning that at both the data collection and analysis stages the structured and unstructured data were always handled together at the same time. Typically, a social network visualisation (or 'sociogram') is a collection of 'nodes' and 'ties' (circles and joining lines) representing individuals and the connections between them. Social network researchers have tested the use of different visual network tools for data collection and report the overwhelming benefits these tools offer network studies (216, 217). However, few of these previous studies on implementation have been conducted in challenging fieldwork settings, such as interviewing hard-to-reach populations in humanitarian or cross-cultural contexts. Furthermore, few of these studies reported using convergent analysis approaches.

Visual tool 1: Data collection

The first tool, hereafter the network 'collection tool', was designed to capture migration narratives and egocentric networks (ego-nets). An ego-net centres around one individual ('ego') and maps their personal network ('alters' and 'alter-alter links'), usually within a specific scope, such as their 'migration network'. This instrument was created as a participatory tool to collect a mixture of structured and unstructured data to capture a fuller picture of the migration process. A series of 'name generating' questions were ordered to reflect the individuals at each dynamic stage of a typical migration trajectory. For example: *Who gave you the idea to migrate?* or *Who did you first talk to about your idea to migrate?* Then later: *Who arranged your job at destination?* Each answer added a node to the dynamic network visualisation that could also be 're-selected' later. For example, a node would be added for a friend that suggested ego should migrate and then re-selected later if that same person arranged ego's job. See Figure 14 for screenshots of the collection tool.

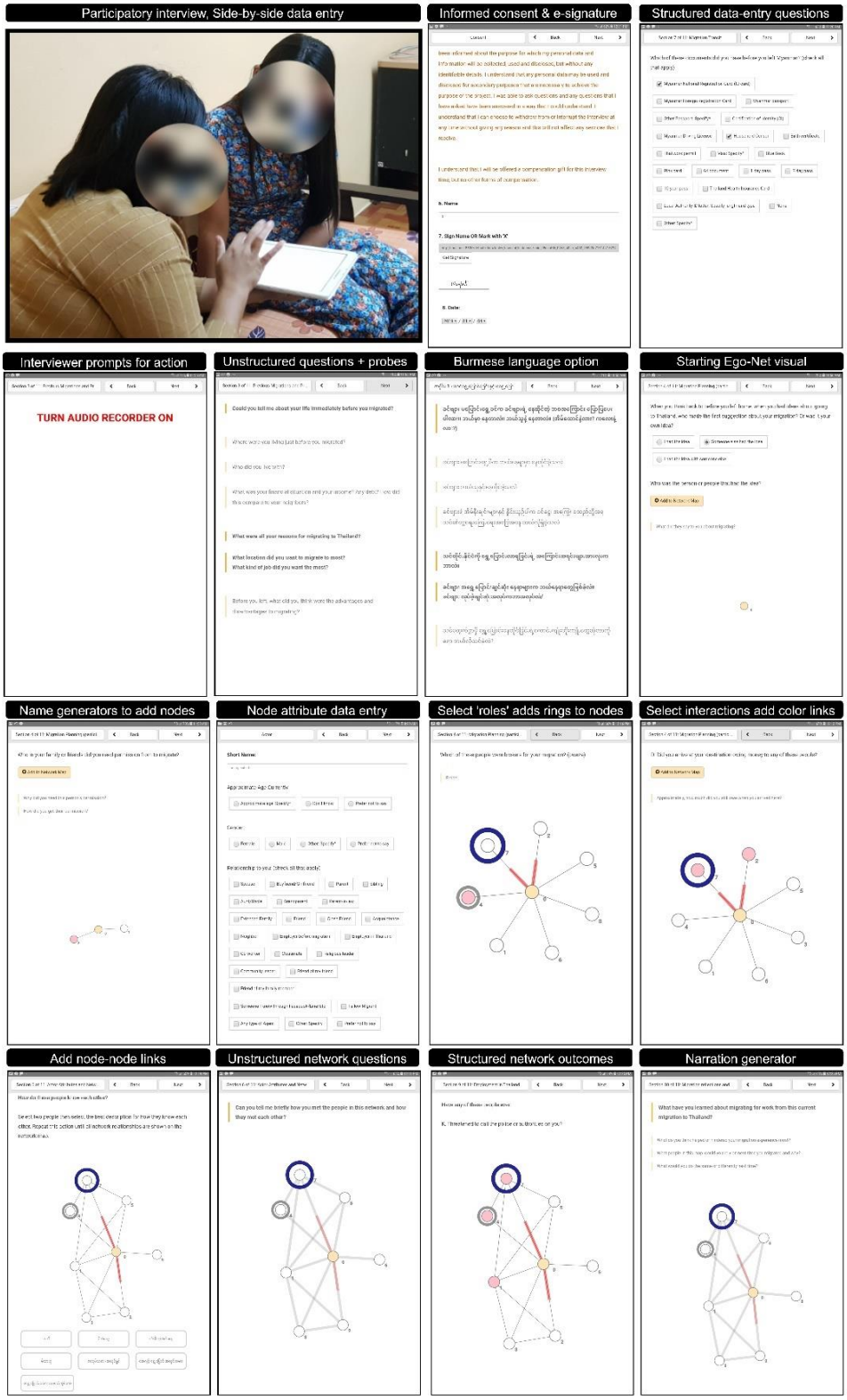

Figure 14. MMSNA study – data collection tool interface

The digital format of the collection tool and of the informed consent helped mitigate challenging fieldwork logistics (e.g., time constraints, multiple remote sites, storing sensitive data offline). The tool was built for Android tablets on top of the open-source application, OpenDataKit (ODK), using the ODK-X[17] framework, which affords customisability while taking advantage of a trusted and tested codebase to handle secure data storage locally. The custom ego-net interface had a force-directed graph layout using the data visualisation JavaScript library D3js within ODK-X (218). The interface displayed and manipulated the real-time database for each interview, which provided immediate 'visual feedback' for the participant and the interviewer to reference during the interview probing (i.e., the ego-net is visually updated after each answer). The visualisation used intentionally limited shapes and colours to represent only essential details that would support probing without distracting or overwhelming the interviewee. For example, all new nodes were initially displayed as white circles but gained details to distinguish key roles or exchanges (e.g., grey ring for 'intermediary', red link for debt).

The digital interface transitioned smoothly between structured data-entry (e.g., network mapping, node demographics, outcome indicators) and semi-structured interview scripts (e.g., open-ended questions on decision-making or interactions). To ease these transitions for the interviewer, the formatting indicated what type of question (structured/unstructured) was being asked and whether it was a *primary question* or follow-up *probe*. Open-ended probes accompanied unstructured and structured questions, where useful. The tool had written prompts to turn the audio-recording on/off to eliminate unnecessary transcript length while maximising any opportunity to capture in-depth narratives even during structured sections. We determined the essential sections for audio-recording during the tool pilot interviews (n=3),

[17] ODK-X, previously ODK2, is a framework that can be used by advanced software engineers and allows for more freedom to customise the interface than the basic ODK interface intentionally designed to have a low-ceiling for non-programmers.

where we observed which sections lent themselves to qualitative dialogue, sometimes without extra prompts or probes. The trained interviewers conducted the entirety of the mixed methods data collection using just the tablet and audio-recorder since we programmed the informed consent, scripts, structured tablet-entry questions, open-ended questions, probes, and interviewer prompts into a single digital interface. Interviewers' training was designed and implemented by the first two authors and included 5 days of intensive group training and then ongoing one-on-one sessions as needed. Training on the use of the tool involved an overview of the tool's structure and applications, user demonstrations, and practical sessions with mock interviews. Additional information on the design, piloting, and sections of this tool can be found in the supplementary materials (Appendix 5).

Visual tool 2: Data analysis

The second tool we developed, hereafter the network 'analysis tool', also employed a convergent mixed methods approach. The analysis tool was a locally hosted, browser-based desktop interface that runs on NodeJS and, again, uses the D3js data visualisation JavaScript library.

This tool visualised all the ego-nets for the 'user' (analyst) to select ego-nets to explore. A selected ego-net was presented alongside a short narrative summary of the ego (migrant) and a condensed table of alters' data (non-ego actors). The interface also calculated the size and density of each network and the 'betweenness' score for each alter node. There were multiple user-controlled features that changed data displays in ways that could facilitate network exploration. For example, alter nodes could be labelled with the structured categorical 'actor type' (e.g., family, intermediary) or short qualitative bios extracted from the transcripts (e.g., "aunt that invited ego to Thailand"). Network IDs could also be sorted by size or density to compare 'less dense' to 'more dense' networks. See Figure 15 for a selection of screenshots of the tools' capabilities.

Network ‘filters’ represented the different dynamic stages of a migration (e.g., decision to migrate, transit). This feature allowed the user to easily query network dynamics both *within* and *across* networks. For example, the user could filter the network only to alters involved in financial transactions with ego and then compare this financial network across multiple ego-nets. See Figure 15 for a screenshot of the network analysis tool. This network analysis interface was designed to facilitate easier navigation and more productive exploration of a mixed methods network dataset. This tool was also envisioned to be used alongside qualitative analysis software, such as NVivo. The pairing of these tools facilitated convergent analysis of the network structure, dynamics, and thick qualitative narratives.

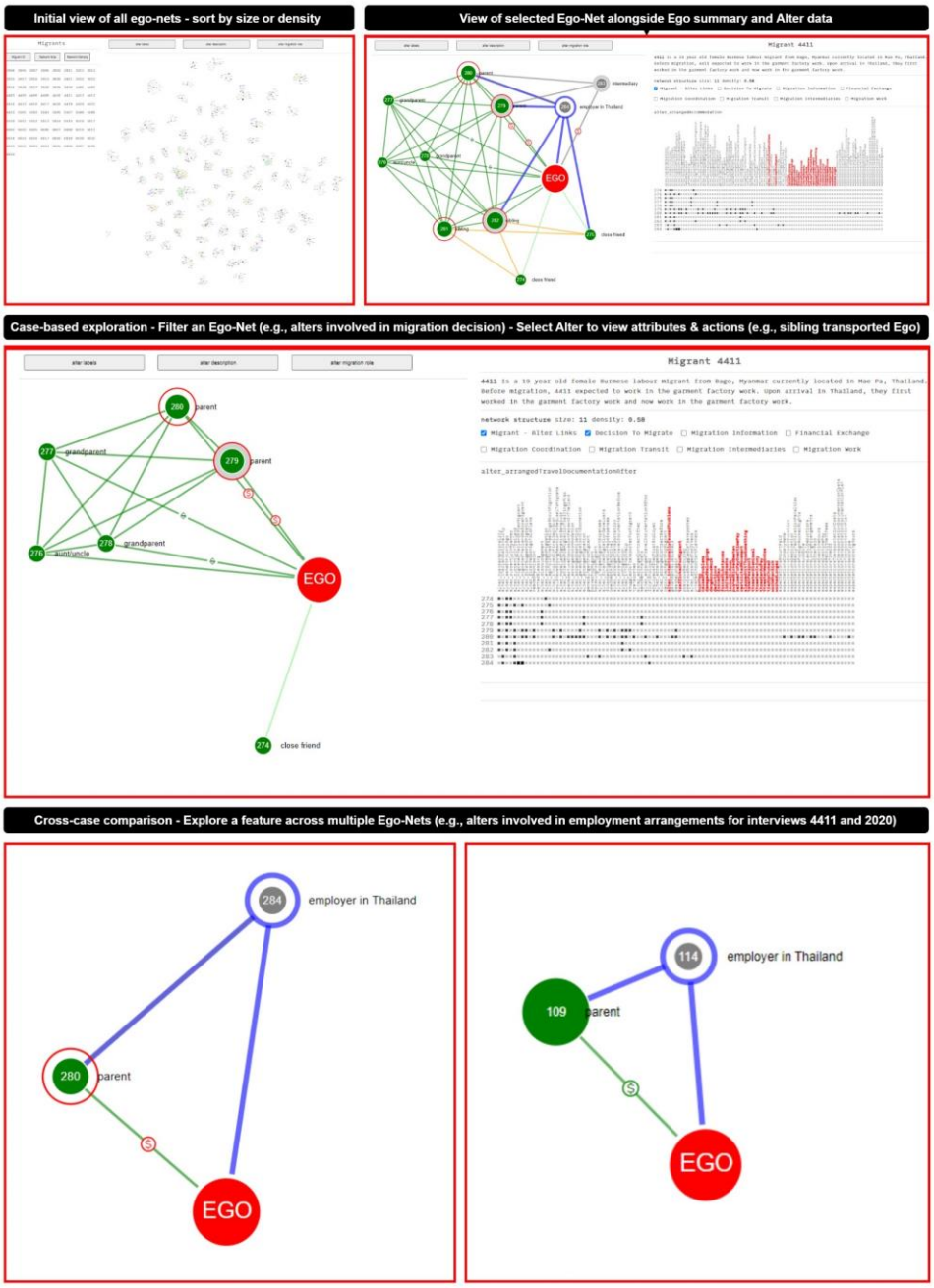

Figure 15. MMSNA study – data analysis tool interface

Readiness for use

At the start of this study, we reviewed existing digital network tools, such as Network Canvas, GENSI, or Enso (previously OpenEddi), but none met our standard for use. For example, most were still in beta testing (i.e., users' acceptance testing) and did not have sufficient use case examples, local data security features, or guarantee of real-time support if issues came up during fieldwork. For various timing, software, language, and design reasons we decided to custom-build these tools to meet our study objectives and logistical requirements. Our team does not intend to develop these tools for wider-use, primarily because appropriate alternatives, like Network Canvas, are now piloted, documented, and available for use with lower technical thresholds than custom tool-building such as ours (219). However, the structure of our two tools could be adapted by any computationally literate individual or team with experience in front-end web development (JS, HTML, CSS), familiarity with D3js, knowledge of interfacing directly with the ODK application, and proficiency using the command line. For those interested in adapting and using these specific tools, the code is open-source and accessible via GitHub (220).

Lessons and reflections

The methodological lessons and reflections fall under two themes: 1) observed benefits of using *visual* tools for MMSNA; and 2) the compatibility of MMSNA and complex systems modelling, such as ABM.

Benefits of visual tools for MMSNA

Broadly, visual egocentric network data collection tools have been reported to reduce cognitive burden for both study participants and interviewers during interviews, ensure uniform data collection, and reduce interview time, as well as being 'enjoyable' for participants (216, 217). Our observations concur with these findings and highlight the additional benefits of using a visual network data collection tool that enabled us to:

- collect a *complex dataset* for each interview;
- efficiently collect *mixed data* (structured/unstructured) simultaneously;
- foster *participatory* interviews; and
- verify the complex data in real-time for greater data quality assurance.

Hollstein and colleagues' describe ego-net visuals as a "narration generator", a means to elicit rich qualitative accounts (216). During piloting, many interviewees shared anecdotes and illustrative examples *during* the ego-net mapping activity, so we added qualitative probing and audio recording during this section. We observed that the visual network that emerged during the mapping was used as a reference for semi-structured questions and made it feasible to collect *complex* datasets from each interviewee not just across the sample (i.e., each interview had multiple actors, links, roles, interactions). The visual tool easily and exhaustively captured the actors, which then enabled the interviewer to probe into the *dynamics*, *interactions*, and *feedbacks* within the network, contributing further to the complexity of each interview dataset. The rich narrative was not just a by-product of the mapping or a means to the mapping. The network visual and narration spurred a continuous exchange resulting in a

fuller yet comprehensible picture of the migration's social, spatial, and temporal development. For example, the visual snapshot of network relationships guided the interviewer's probing on specific links, such as an 'encouraging friend' linked to a smuggler: *How did they know each other? For what purpose? How did their relationship influence ego's migration decisions?* Likewise, when the narratives became thick in detail (e.g., multiple people interacting across stages or geographies) the interviewer could ask the interviewee to use the visual and node 'names' to talk through the story, allowing a thicker description of the network *process* without getting lost in non-specific pronouns. This technique also identified any missing actors from the network.

The multiple approaches to capturing the network, narrative, and exchange between them required us to ask different styles of questions leading to a collection of 'mixed data' (structured/unstructured). The visual ego-net provided a focal point that was maintained even when the styles of questioning or mode of capturing data changed (e.g., multiple choice, digit entry, open-ended). The visual reference became an efficient way to progress quickly through different sections, question formats, and audio prompts without losing traction of the interview dialogue. This was a key takeaway from piloting – the visual ego-net became the narrative 'thread' throughout the interview that afforded us the flexibility to choose the *best* question format for a specific data point. The interview was structured around capturing the narrative and network, not the type of data being collected. Since this was a new approach to a flexible mixed data collection tool, we decided that audio-recording most of the interview would minimise any lost qualitative data due to the fluidity and transitions between structured and unstructured sections. For example, even the structured questions on alter demographics sometimes elicited qualitative descriptions of relationships (e.g., "They are my friend, but we were co-workers first and they helped me when I had troubles with the employer.").

The visual tool also fostered a participatory approach to knowledge-production with the team of Myanmar interviewers and the migrant interviewees. Migration subject experts argue that there is both a moral imperative and scientific benefit to partnering more closely with target populations during research activities (221, 222). The feedback from interviewers and interviewees indicated that they enjoyed the visual aspects of the tool and the interviewers felt this fostered longer interviews because interviewees were actively engaged in the process. This concurs with Hollstein's comparative study that found interviewees preferred the open-network tools to other alternatives (216). The visual ego-net, which was co-authored by interviewer and interviewee side-by-side with view of the tablet, invited participants to offer their own network observations to our analysis of the relationships, interactions, and dynamics. The tool enhanced interviewees' comprehension of our line of questioning and invited them into the analytical task for which they were arguably the best equipped to perform. In fact, when one interviewee was asked about an alter's influence on his plans, he interjected that it was "not as systematic as all that", which indicated he understood the patterns of interaction and effect we were trying to identify and helped steer us away from irrelevant lines of probing. We specifically designed the data collection tool to enable the interviewees to better understand and contribute to the research, with the hope of performing less 'extractive' and more collaborative research.

Lastly, but importantly, the real-time visual feedback functioned as a partial data quality check during data submission. The entered data did not disappear to the instrument back-end. The nodes and links were visible, which meant clarifications could be made. There were cases where interviewees observed and corrected any errors, for example, saying 'not *that* aunt in Myanmar' but 'that other aunt in Thailand already' that loaned her money. This participatory process of interviewer-interviewee co-authorship encouraged continual quality checking in real-time.

The digital format of this tool made it possible to securely encrypt sensitive data in remote locations and facilitated the participatory approach and quality checks. For example, we programmed the tool to have both English and Burmese versions via a simple language setting button. This meant the interviewee could read and participate in Burmese and the bilingual research team could review and quality check the interview data in English immediately after completion.

Now we will describe some of the benefits of using a network data visualisation interface for the mixed methods analysis. The analysis tool and its user-controlled features enabled us to:

- more easily explore a highly complex dataset;
- conduct in-depth case-based and cross-case comparisons; and
- envision new ways of communicating complex migration narratives.

One concern in collecting such complex network data, is determining the best way to gain insight about the various datapoints. The visual analysis tool provided an interface to explore the complexity by viewing different combinations of data points to seamlessly transition between lines of inquiry. This allowed the user to become familiar with a narrative's complexities by pulling insights from all these different 'views' of the complex network. This exploratory approach facilitated in-depth case-based summaries followed by thematic cross-case comparisons. For example, a densely packed group of 'intermediaries' in one network revealed the composition of a smuggling group. Turning on the 'transit' filter and scrolling through other ego-nets was a way to ascertain if this was a common smuggler network, an outlier, or maybe an intermediary composition that applied to all intermediary types.

In the process of exploring and making sense of the complex data through a visual interface, we observed the integral part that visual modularity and comparisons can play in comprehending complex migration narratives. This perspective provided an illustration of how best to present complex and

dynamic networks in ways that captured the in-depth process in a single migration and highlighted trends or points of departure across migrations. These narrative visual network representations can display connections and patterns not immediately obvious when the data are solely represented in text, audio, or static imagery after survey completion.

Integrating MMSNA and complex systems modelling

The second area of methodological learning was on how MMSNA, using these visual tools, could be applied to inform complex systems modelling. Complex systems, such as the one defined by migration systems theory, are made up of many heterogenous entities at different levels of aggregation (e.g., individuals, households, communities, industries) whose interactions with each other and the wider environment give rise to dynamic and emergent outcomes. Posing and answering questions pertaining to such multi-level, complex systems require methods that can identify a range of entities and interactions, explore the dynamic changes, and analyse the emergent patterns.

Mixed methods network approaches are applauded as being able to capture both the *structure* and *process* that are equally integral to a network (223). The structure includes the actors and connections between actors (e.g., relationships, interactions) and the process includes the dynamic stages of interactions, inputs and outputs of decisions, and events that might unfold over different spatial and temporal scales. The *structure* and *process* identified by MMSNA offers ideal insights to determine the *entities* and *dynamics* of complex systems.

There are many examples of complex systems models that incorporate networks into the model design and conduct SNA with simulation observations, but, to our knowledge, this is the first example of an ABM that uses MMSNA to strategically collect and analyse the complex datasets needed to inform an ABM's agents, properties, and rules. Complex systems thinking and the multi-agent methods (e.g., ABM) informed the choice and

design of the MMSNA techniques and in turn the outputs of the MMSNA informed the design of the ABM's agents, environment, and rules (Table 15).

Table 15. MMSNA as a method to inform an ABM

Data points	Findings	Translation to ABM
Nodes	actor types, frequencies, and attributes	Agent classes and properties
Node-Node ties	relationship types, frequencies, and interactions	Agent-Agent links and interaction rules
Network dynamics	emergence of networks across migration stages	Temporality of Agent-Agent links and interactions; Temporality of Agent decision/behaviour rules
Network narrative	network process	Agent decision/behaviour rules; Agent-Agent interaction rules; Agent-Environment rules; Conditions for rules Mid-process outcomes and final outcomes

Figure 16 summarises the stages of the study design (data collection, primary analysis, and simulation) that built on each other and the multiple tools, data, and analysis that contributed to the final empirical-based ABM.

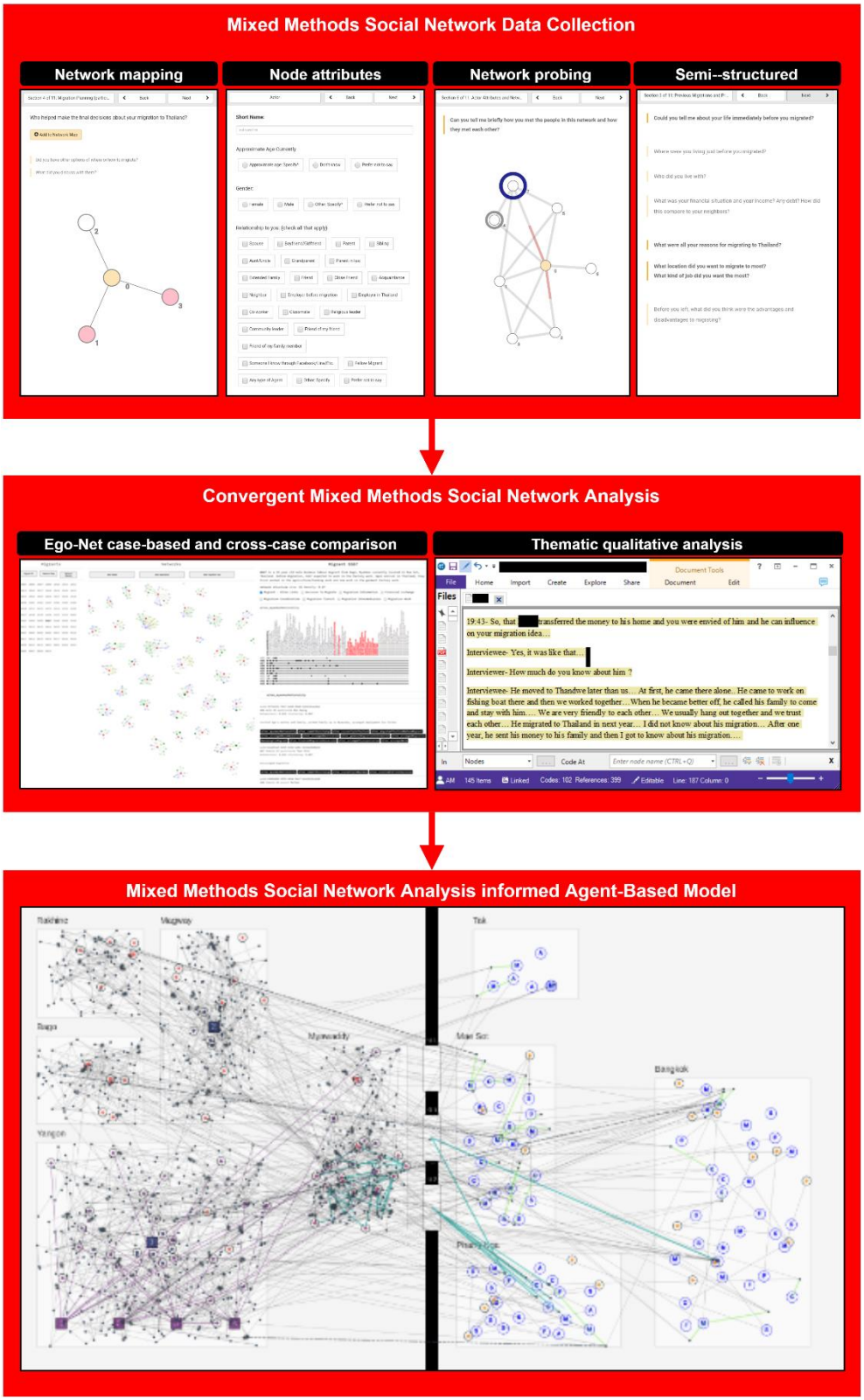

Figure 16. Mixed methods complex system study design

Limitations

These tools have not been tested in other contexts and so we cannot conclude with certainty that they would have the same success. Likewise, these tools have not been tested with larger sample sizes since this mixed methods study had a mid-size sample appropriate for collecting qualitative as well as structured network data. However, similar paper-based network mapping tools have been tested with larger samples in other contexts and were found to be acceptable to the users and efficient for meeting research aims (216). Conducting interviews with these tools can limit the burden of network data collection but are still intensive tools to use compared to conventional paper-based surveys or qualitative interview scripts. Furthermore, digital data entry can simplify data storage and security procedures and ensure more accurate data capture. However, to mitigate the challenges in using these tools, we conducted extensive training, piloting, and iteration with the research team to ensure we achieved a user-centred design process which resulted in the most appropriate and least cumbersome tool for the interviewers and interviewees.

Conclusion

Efforts to address public policy challenges that occur amidst real-world economic, social and political influences have been attempted throughout most of modern civilisation. However, over the past several decades, because of growing recognition of the complex nature of social problems—and the potentially helpful role of complexity science—there have been greater calls for research that can take account of the numerous interacting influences that can foster or stymie intervention strategies. There is currently much greater understanding that interventions for complex problems in complex settings are likely to require multi-component intervention designs to address the multi-level mechanisms that can lead to change. Identifying intervention approaches that can tackle the actual array of factors for a problem in a particular context is an ambitious but feasible feat *if* we develop, test, and share new ways of doing complex systems research. Particularly for dynamic phenomena like migration, which involve diverse populations and a wide variety of potential influences, mixed methods complex systems approaches offer promising new methods to capture heterogeneous populations, ongoing interactions and feedback loops that shape how multi-level systems affect individuals. Methods that have the capacity to examine how a system interacts are important because of the difficulties of any single method to adequately identify the influence of numerous properties and variables within complex phenomena.

Through this case study, we conclude that MMSNA is a complex systems approach that is also compatible to informing complex systems modelling. MMSNA techniques can capture the range of data points needed to inform an empirically-based complex system model, such as an ABM. Moreover, visual MMSNA tools provide practical, efficient, engaging, and insightful ways to collect and analyse rich complex datasets in an interactive activity that is acceptable and enjoyable for both the interviewers and interviewees. Visual tools offer unique capacities to simultaneously collect the various

formats of these data points as well as visualise these complex datasets in a cognitively accessible format for convergent analysis. These techniques can be especially useful when conducting research with individuals who have lower literacy levels or learning challenges or are marginalised. Particularly when trying to probe subjects that have multiple or potentially confusing aspects or in situations where people's different independent actions influence each other and various aspects of the context where they operate. Complex social system modeller, Joshua Epstein, argues that the future of explanatory research will be the ability to 'build' or 'grow' the phenomena by understanding the micro-rules of the many interacting actors, entities and systems. This paper aims to advance our methodological approaches to 'growing' and understanding complex systems by first improving the way we collect and analyse complex datasets so they can elucidate how these systems operate as a whole. We hope this work offers new contributions to the promising fields of egocentric network data collection, MMSNA, empirically-based ABMs, and complex systems research design. In particular, we anticipate these methods can be used in migration-related research to help programme and policy decision-makers take account of the many factors that will affect the implementation of most interventions aimed at making migration safer and fairer.

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RESEARCH PAPER COVER SHEET

SECTION A – Student Details

Student ID Number	388074	**Title**	Miss
First Name(s)	Alys Mary		
Surname Name	McAlpine		
Thesis Title	Mediated labour migration in the Myanmar-Thailand corridor and precarious outcomes: a mixed methods social network analysis and agent-based model		
Primary Supervisor	Cathy Zimmerman		

SECTION B – Paper already published

Where was the work published?			
When was the work published?			
If the work was published prior to registration for your research degree, give a brief rationale for its inclusion			
Have you retained the copyright for the work?*		Was the work subject to academic peer review?	

SECTION C – Prepared for publication, but not yet published

Where is the work intended to be published?	Social Network Journal
Please list the paper's authors in the intended authorship order:	Alys McAlpine, Luke Demarest, Ligia Kiss, Cathy Zimmerman
Stage of publication	**Submitted**

SECTION D – Multi-authored work

For multi-authored work, give full details of your role in the research included in the paper and in the preparation of the paper.	I led the study design, tool design and piloting, fieldwork, data cleaning, data analysis, and authored the first draft of this paper.

SECTION E

Student Signature	[redacted]
Date	27-06-2021

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Date	27-06-2021

4.3 MMSNA findings

4.3.1 Preamble to Paper 3

This paper is the first of two papers presenting the original empirical findings of this thesis. The paper aims to describe the intermediaries, networks, pathways, and processes that shape the complex labour migration system between Myanmar and Thailand, and, ultimately to capture the lived-complexities of migrants' experiences. The study applied mixed methods social network analysis (MMSNA) techniques using the visual network tools described in Paper 2. The MMSNA data collection and analysis were both designed with ABM in mind and the descriptions of people, interactions, and experiences in this paper offered the insights used to inform the agents, environment, and rules of that ABM (Paper 4). What makes this an especially unusual paper to inform an ABM is the way that it draws on qualitative data from the study participants.

This paper has been submitted to the *Social Network Journal*, a journal with specific interest on the emergence and development of social networks and their consequences.

4.3.2 Paper 3

Labour migration intermediaries, networks, and pathways in the Myanmar-Thailand corridor: a mixed methods social network analysis study

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Keywords: labour migration, intermediaries, decision-making, mixed methods, social network analysis

Acknowledgements: AM led the study design, tool design, data collection, analysis and write up; LD programmed the data collection tools and data visualisations; LK and CZ supervised this work as part of AM's doctoral degree; AM wrote the first draft of this paper; and all authors revised and contributed to the final draft.

Abstract

The aim of this study was to describe the social and intermediary networks that influence and facilitate labour migration between Myanmar and Thailand. The study design adopted a complex systems approach and used mixed-methods social network analysis techniques and includes a unique narrative feature that draws on 81 in-depth interviews with individual migrants from Myanmar. Fieldwork relied on a custom-designed participatory egocentric network mapping tool that enabled the simultaneous generation of structured network data and quotes from individual migrants who are represented in the networks. The analysis integrated descriptive quantitative, thematic qualitative, and visual case-based and cross-case comparisons. The results indicate that individuals have different migration motivations, decision-making processes and personal influences and that there is a broad range of actors that form a migration network that evolves over time and geography. Migrants make decisions based on social influences, personal preferences, and different types of access to intermediaries and, importantly, they choose their final migration pathway under various uncertainties. Intermediaries are a broad and varied group of actors that assume different roles in different individual migration pathways *and* at different stages of those pathways. Migration trajectories are relatively pathway-dependent once a migrant makes initial plans for how to migrate. These plans are often made near-simultaneously alongside the decision to migrate (e.g., invited to migrate and the offer includes the migration plans). Migrants did not readily attribute risk or blame to specific network actors or risk to specific stages of migration. Across each individual's narrative, it was not possible to make conclusive characterisations of certain categories of intermediaries as risky or protective choices.

Introduction

Migrants frequently rely on others to finance, inform, and coordinate their migration, which is why many popular migration corridors (e.g., Mexico to the USA) show evidence of established migration networks (224). In light of this social-embeddedness, migration researchers are increasingly applying social network analysis (SNA) methodologies to a range of topics, such as social assimilation at destination (225, 226), transnational social capital (112, 227), flows of labour remittances (228, 229), and trends in labour migration (230). However, most network research on labour migration addresses 'highly-skilled' migration (231–233) or labour migration to high income countries (234). There is a substantial gap in the literature on the role of networks for low-wage labour migration, especially within low- and middle-income countries. This paper presents findings from a mixed methods SNA (MMSNA) study on the social and intermediary networks that facilitate low-wage labour migration in the Myanmar-Thailand corridor.

Background

Low wage labour migration, hyper-precarity, and exploitation

Low wage labour migrants are often in situations of 'hyper-precarity', which is what sociologist Hannah Lewis conceptualises as a state of compounded precarity resulting from a migrant's socio-legal status and low standing in the labour market (26, 62, 235). This precarity often makes migrants more vulnerable than native workers to a range of work-place harms and abuses, including high rates of wage theft (46) and disproportionate rates of occupational injuries and morbidity (6). Migrant workers also face increased exposure to more severe forms of labour exploitation. For example, global estimates suggest that 25 million people are in situations of forced labour or human trafficking and that nearly a quarter of this population began their journey as international labour migrants (4). As a result of these linkages between labour migration and exploitation, international initiatives to promote *safe* migration have become synonymous with preventing human

trafficking or 'modern-day forms of slavery' (236). Emerging evidence on the drivers of human trafficking points to the strong influence of the structural mechanisms and local networks associated with labour migration, especially labour recruitment systems (68). However, until recently, most labour migration interventions have focused on *individual* level mechanisms, such as awareness-raising to encourage individuals to migrate legally, retain possession of their documents, and other 'self protective' measures, which rarely account for the complexity of the structural, social, and systemic aspects of labour migration.

Associations between unfair recruitment practices (e.g., exorbitant fees, contract swapping, use of deception) and labour exploitation has driven the 'fair recruitment' agenda to the forefront of labour exploitation prevention (65, 69, 71, 72). The International Labour Organization (ILO) describes fair recruitment as "recruitment carried out within the law, in line with international labour standards, and with respect for human rights, without discrimination" (237). The ILO recommends a set of fair recruitment principles that include, for example, promoting freedom of association and collective bargaining, providing transparent and accurate information about employment conditions, and, importantly, eliminating recruitment fees (i.e., the 'employer pays' principle) (11). However, despite accelerated efforts to establish a global model of fair recruitment, definitions about what is meant by 'recruitment', who is a 'recruiter' and the definitional boundaries of recruitment practices are still relatively opaque and highly context dependent (61). Additionally, there is limited understanding of how recruiters and other intermediaries interact with migrants' wider social and migration networks, and how they influence plans and decisions to migrate.

Moreover, fair recruitment rhetoric relies on simplified dichotomies between legal or illegal (or 'irregular') migration, licensed or unlicensed recruiters, and permitted or prohibited recruitment fees. These binaries are unlikely to reflect the diversity of migrants' lived experiences of recruitment

and migration in less regulated migration corridors, such as between Myanmar and Thailand. This research adopted a migrant-focused lens that recognises the complexity and dynamic nature of migration-related systems of recruitment and migration intermediaries to explore the links between complex causal mechanisms, such as migrant networks and pathways, and adverse labour migration outcomes.

Myanmar-Thailand labour migration

Thailand is the highest net-receiving country of migrant workers in Southeast Asia and Myanmar migrants are the highest proportion of migrants in Thailand (83). According to the International Organization for Migration, most (91%) Myanmar immigrants in Thailand entered using 'irregular' channels (82). In 2003, Thailand and Myanmar signed a Memorandum of Understanding (MOU) which is now the bedrock for current labour migration policy in this corridor and includes a required step of formal recruitment through registered recruitment agencies (238). In the MOU system, each migrant's work permit is administratively linked to a named employer and valid for two years, permitting the migrant does not change or lose employment. If a migrant wants to switch employers, they must complete a formal resignation process, which includes acquiring the signature of their current employer. See Appendix 6.1 for a detailed diagram of the MOU process.

The immigration policies that govern Myanmar-Thailand migration are notoriously opaque and subject to regular updates and additions (83, p. 27–41). Even in the regulated MOU channel, many migrants are forced to rely on informal intermediaries to help them navigate the administrative processes. Various migrant organisations and migrants themselves have reported that it is unreasonable to expect migrants to keep track of the many changes and understand their options (83, 92). In fact, recent research on labour migration to Thailand by the NGO Verité concluded that the MOU process has not successfully replaced irregular migration pathways because

migrants find the MOU process to be complicated, costly, and time-intensive (91). The report states that increasing NGO and government promotion of legal migration channels is motivated, in part, by the assumption that greater regulation and transparency will lead to worker protection, but the authors explain that this assumption was not supported by empirical research findings.

Labour migration from Myanmar to Thailand is often mediated by individuals who form the chain or network of agents that facilitate migration to a destination and/or job (i.e., 'intermediaries'). Katharine Jones, a subject expert on labour migration mediation, offers the following definition of intermediaries:

> "An intermediary is an actor or institution that fosters, facilitates or sustains human mobility. The mediating or brokerage process is relational and often involves interactions of multiple actors operating within complex local-global, socio-economic, cultural and political environments. The practices of intermediaries often blur the boundaries between commercial and non-commercial, private and public, state and market, formal and informal, legal and illegal due to the complex nature and conditions in which this 'middle-space' exists." (61) (Jones, 2020: 15)

Table 16 summarises some of the definitions used by organisations, such as Verité and ILO, to describe intermediary and migrant actors in the Myanmar-Thailand context (91).

Table 16. Myanmar-Thailand corridor actors, adapted from NGO reports (80, 91)

Actor	Description
Irregular Migrant	1. Migrant that use informal or unofficial routes to enter Thailand outside of the agreed Myanmar-Thailand MOU labour migration process [Verité] 2. Migrant worker who leaves, enters, stays, or works without the necessary authorization or documents required under the Thai laws [IOM]
'MOU Migrant'	Migrant worker who migrates to Thailand legally and adheres to the MOU agreements between Thailand and neighbouring states [ILO]
Private Recruitment Agency (PRA)	Third-party companies licensed by the Myanmar or Thai government to recruit and place workers in Thailand [Verité]
Informal Agency	Third-party bodies that provide informal services to jobseekers in Myanmar or Thailand [Verité]
Labour Broker	1. Informal intermediaries that provide services to enter Thailand [Verité] 2. Unlicensed labour market service provider, including individual brokers and networks, with or without remuneration [ILO]
Subagent	Informal intermediaries that mediate between jobseekers and PRAs, usually Myanmar village-level brokers [Verité]

Often these definitions do not maintain clear distinctions between different actors or roles. For example, both labour brokers and village-level agents are 'informal' intermediaries, and in practice, the broad services of a broker may be identical to the mediating role of a village agent (e.g., they both offer transport to Yangon, or they both offer support in applying for passports). Additionally, the term 'irregular migrants' indicates that migrants did not use a licensed recruitment agent but does not indicate which intermediaries or pathways they *did* use. The relatively 'flexible' categorisation means that many mediating actors can fall into multiple groups and that individuals facilitating irregular channels may not be included in these definitions at all. These categorisations also assume that an intermediary only works in a singular capacity when in fact intermediaries may evolve their business model to meet demand or work across multiple pathways. For example, a sub-agent may in some cases broker a migrant's connection to PRAs but may also assist irregular migrants in 'non-MOU pathways'.

A team of researchers from Johns Hopkins University and the Thai NGO Labour Rights Promotion Network interviewed 430 Myanmar migrant workers in Thailand using Respondent Driven Sampling (RDS) methods and found that over 90% had used a "recruiter/transporter" and the report also said this intermediary category was interchangeable with the concept of "brokers" (239, p. 37). These findings indicate widespread involvement of informal intermediaries in migration pathways but do not provide clarity on possible distinctions between informal intermediaries. A more recent study led by the University of Sussex confirmed that Myanmar migrants prefer and continue to use informal intermediaries to avoid being tied to a singular employer and type of work, as is the case in the MOU process. Each of these studies, including the Verité report on MOU migration, report that intermediaries play an essential role across all stages of migration.

The influence of social networks on migration flows is a common phenomenon in many migration corridors (224), but it is an especially common feature of migration corridors across highly porous borders, such as between Myanmar and Thailand (83). IOM reports that 74% of incoming Myanmar migrants to Thailand said that her/his employment at destination was arranged by family or friends (240). Additionally, Verité reported that individuals migrating through social networks were able to gain a more accurate understanding of the living and working conditions compared to migrants migrating through formal MOU channels (91).

Dynamic migration networks

Dr Louise Ryan, a sociologist of migration networks, emphasises that research on migration networks needs to go 'beyond the snapshot' to consider the 'complex temporality' of these networks (241). This is particularly apt for research on migration networks that emerge from decision-making, planning, and interactions across multiple stages of a migration trajectory (e.g., pre-migration, planning, transit, destination).

Migration theory posits that migration, as a dynamic process, has patterns of events, interactions, and risks specific to different stages of migration (5, 114). The nature of migration means that any research trying to identify *mechanisms* (i.e., influential parts of the process) to inform safe migration interventions needs to consider the timing, stage, and location of possible mechanisms, since these migration networks and corresponding pathways do not represent a uniform, static exposure throughout the migration.

Research aim

This paper aims to identify and describe the migration networks that shape the Myanmar-Thailand labour migration system (e.g., actors, interactions, networks, processes, geographies) and individual pathways (i.e., an individual's migration process within that system), including preliminary insights on these networks and pathways as causal mechanisms for migration outcomes, which can include precarity, hyper-precarity and exploitation. The objectives of this study are to: 1) map and detail the actors and structure of egocentric migration networks; 2) describe the dynamics and interactions within these networks; and 3) explore how these emergent migration networks influence and are influenced by individual migration pathway decisions.

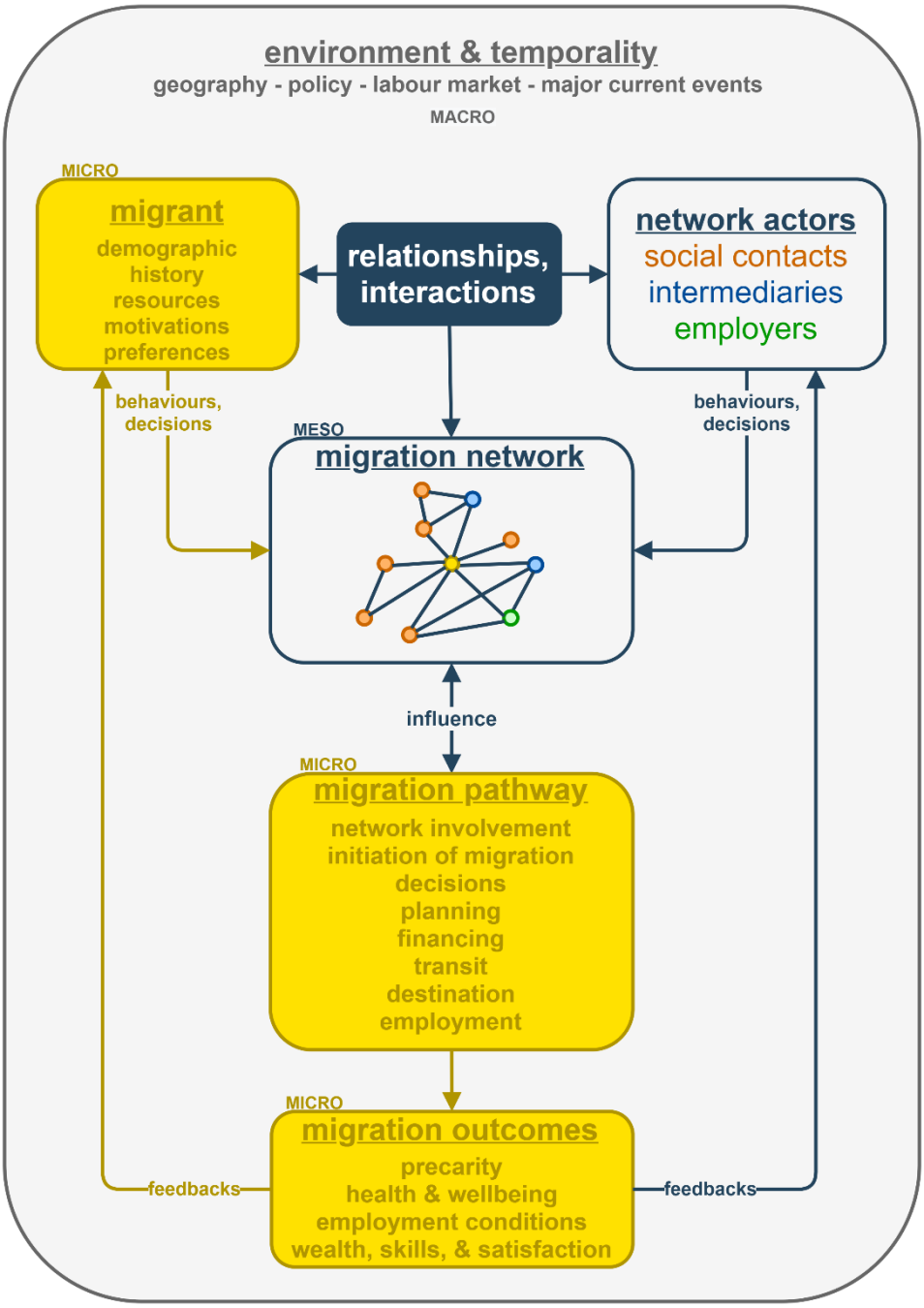
This paper also aims to make a methodological contribution to mixed methods social network analysis (MMSNA) research using novel visual MMSNA tools for data collection and analysis (242). This paper presents joint-displays of structured egocentric network visuals alongside qualitative narratives from the migrant interviews, which highlights how migrants' actual experiences are represented in the network and vice versa, how the network was built based on data from the participants.

Methods

Complex low-wage labour migration system conceptual framework

The study design was informed by an integrated body of theoretical work. First, it drew on migration network theory, which poses that migrants' social capital influences the decisions, costs, or benefits of migration (111–113). Second, it was informed by a combination of complex systems and migration systems theories, which explore how collective micro-behaviours (actions of *individuals*) as well as the meso- or macro-level entities (e.g., networks, industries, environment, immigration policy) shape the dynamics and feedback in emergent migration systems (104, 107, 109, 243).

This study focused specifically on the interactions between the migrant and those individuals who influenced and mediated each migrant's labour migration (i.e., *egocentric* network or 'ego-net'). The methods, tools, and analysis for this study were guided by an original conceptual framework developed for this work (Figure 6, repeated from Chapter 2) that depicts labour migration as a complex system of individual actors, behaviours, networks, pathways, and feedback (see Appendix 2 for earlier iterations of this framework).



Repeated Figure 6. Complex low-wage labour migration system conceptual framework

Mixed-methods social network analysis

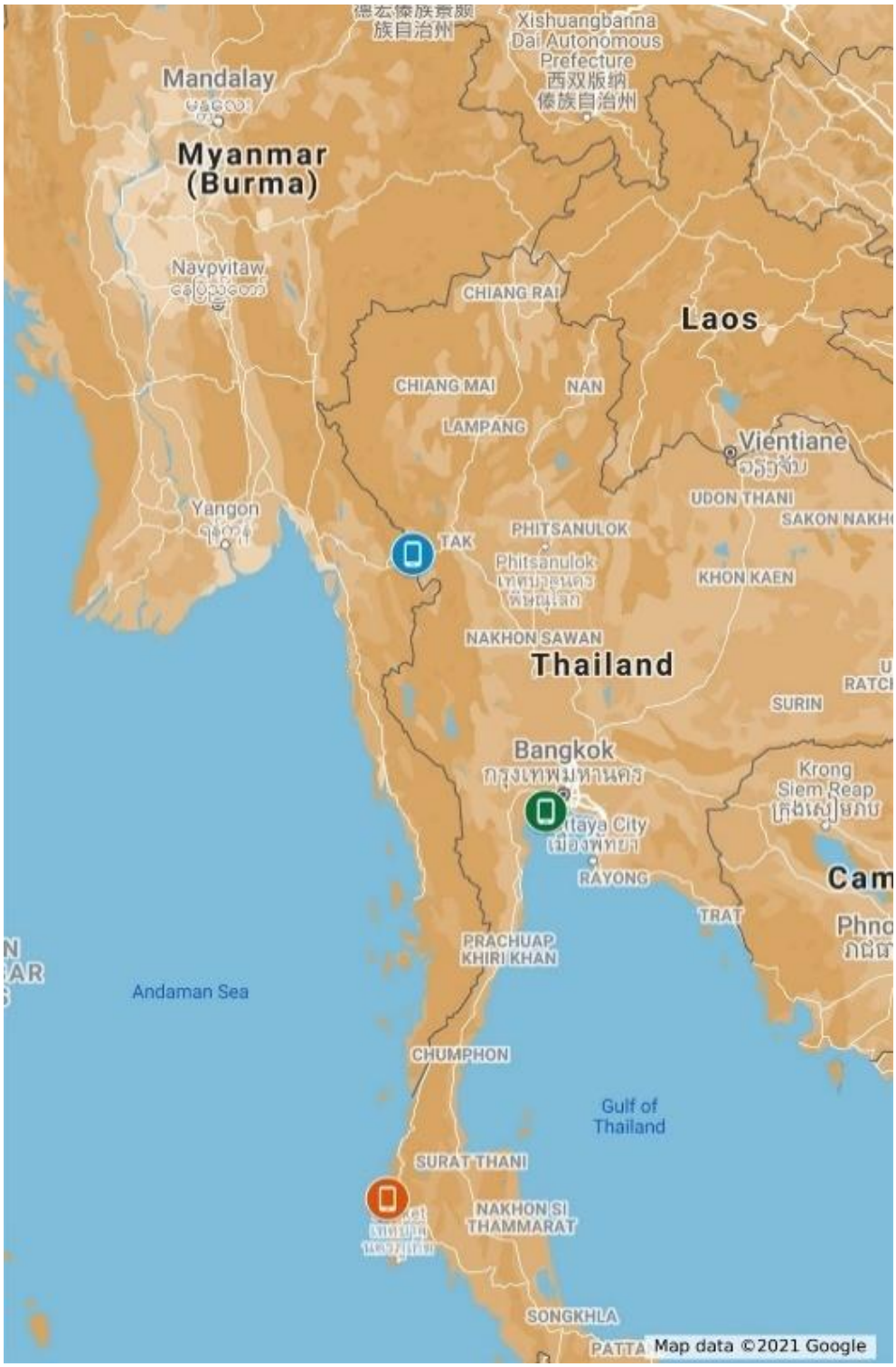
Using SNA techniques, we collected and explored *relational* data from migrants, which were pertinent to their migration as a socially-embedded *process* (e.g., who influenced decisions, coordinated stages, made introductions). Structured network mapping is the most appropriate way to uniformly capture network composition (i.e., nodes and links, or 'network sociograms') and qualitative methods are well-suited to capture the network *process* (i.e., interactions, dynamics, events). This study used structured network mapping and, importantly, semi-structured qualitative interviews to capture data on migrants' ego-nets (i.e., the network of actors involved in the migration with the migrant – 'ego' – at the centre and the individuals they describe in their network – 'alters' – around them) and their individual perceptions and experiences.

This paper presents a mixed methods social network analysis (MMSNA) of low wage labour migration networks using data collected from Myanmar migrant workers in Thailand. An egocentric network is one that centres on one individual and maps the individuals they relate to within a specific context or interaction type (e.g., social support, workplace culture, or in the case of this research, labour migration). Integration of unstructured and structured data and methods was built into each research stage, including the design of the conceptual framework and study tools, as well as data collection, analysis, and visualization. MMSNA is a way to analyse relational data as both *structure* and *process*, which was done concurrently during this study (i.e., *convergent* mixed methods).

Sample. The study sample included male and female migrant workers who were age 18 years or older, from Myanmar, currently living in Thailand, and had migrated to or within Thailand in the past 5 years. Due to both challenges in identifying this hard-to-reach population and ethical considerations around safety and referral services, we used purposive convenience sampling from our Thai NGO research partners' service

beneficiary groups and within their outreach areas. We used a quota sampling approach to interview approximately 50% identifying females and 50% identifying males, as well as individuals working in a variety of employment sectors in Thailand (agriculture, manufacturing, seafood/fishing, garment production, domestic work). Additionally, as this study aims to explore the range of migration networks and pathways, we also purposely sampled a mix of individuals who migrated with the support of different actors. The sampling approach reflected the aim to cast a wide net to explore diverse migration narratives to account for the range of migration networks and pathways in the Myanmar-Thailand corridor. In total we interviewed 100 migrant workers across three different data collection sites (Figure 8, repeated from Chapter 3). This paper presents analysis of 81 interviews since 15% (n=15) of the total number interviews were randomly partitioned in each data collection site for future model validation[18] and four interviews were excluded based on incompletion (n=2) or ineligibility (n=2). The sample size for this study is slightly larger than the recommended 20-50 interviews based on experts' experiences in reaching qualitative saturation (244). It was not feasible to use the concept of saturation to determine a stopping point for data collection because of challenges related to coordinating interview transcription, translation, and analysis within the fieldwork timeline restrictions. Therefore, this larger sample was designed to meet saturation and account for potential systematic differences in migration behaviours across the three data collection sites and the potential for thin interview transcripts when asking about sensitive topics, such as undocumented migration, and the opportunity for a broader descriptive comparison of the structured network data and visuals.

[18] This study will include a second stage of analysis using the findings from this MMSNA to inform an Agent-Based Model (ABM). To validate the ABM, a set of randomly partitioned interviews were not used for the primary analysis or to inform the initial model rules. The partitioned interviews were later analysed to assess whether the ABM rules, based on the MMSNA, held true in the interviews that had not yet been reviewed by the researchers.



Repeated Figure 8. Data collection sites

Data collection. These data were collected using participatory egocentric network mapping with a novel visualisation tool that was designed and piloted specifically for this study (242). Network visualisations can be used as a tool for data collection, data analysis and data dissemination (245). For this study, network visualisations were used at all three stages. Part of this work included designing and piloting a participatory and visual ego-net data collection tool that could be administered on a tablet and used in challenging fieldwork settings. Interviews with each participant consisted of both structured sections (tablet-based data entry) and semi-structured sections (audio recorded) and lasted for an average of 90 minutes. The structured network data were visualised in real-time on the tablet interface to allow the interviewee to comment on the network structure (i.e., size and shape) and narrative (i.e., relationships and interactions) and provide the interviewer with a visual tool for further probing during the semi-structured portions of the interview. The data collection tool is detailed for methodological learning elsewhere (242). Many of the outcome indicators were informed by the ILO's indicators for unfair recruitment and forced labour (246), which have been used in similar surveys on migration and trafficking in the Mekong region (56, 58).

In brief, this tool consisted of name-generating questions that populated the network visual with nodes by asking about *who* did *what* (e.g., *Who first had the idea for your migration?*). Follow-up questions then populated each of the nodes with attribute data (e.g., demographics) and additional questions were asked about events or interactions that could then be assigned to specific nodes (e.g., *Who in this network gave you the most valuable help?*). The interview strategically focused on the migration steps to identify the actors versus asking about specific types of actors (e.g., family, intermediaries) and *then* defining what their roles were. The aim of this strategy was to focus on the migration narrative and not assume who the actors of significance would be.

Finally, the tablet-interface also presented open-ended questions with prompts for the interviewer to turn the audio recorder on when necessary. The open-ended questions probed on the network narrative, for example, how the different actors knew each other, more descriptions of how the intermediaries worked, or what interactions were most influential in the migrant's decision making.

Intermediary classifications

An important part of this research was identifying the presence and roles of intermediaries in the ego-nets. Instead of asking, "*Did you use a broker?"*, the intermediary classifications were assigned to network nodes after the migration network was fully mapped. This approach assumed that any important intermediary actors would have been named in the process of describing their migration stages. This allowed for a migrant-led description and classification of these actors in relation to their migration narrative instead of leading with any terminology that did not correspond to how different migrants knew or used these terms.

After the ego-net map was drawn, the interviewees could assign select 'intermediary classifications' to any of the alters that they had previously described. These classifications included the intermediary terminology used in the Myanmar-Thailand corridor. We identified the key terms during tool development and piloting through informal cognitive interviews and discussions with Burmese speakers who were familiar with migration rhetoric, such as migrant workers and experts on labour migration in Myanmar. Through this process, we identified six key intermediary terms used by Myanmar migrants, which we classify and describe as the following:

1. Recruiters. The English word 'agent' has been adopted into Burmese vernacular and in relation to migration this word is generally used to mean licensed recruiters. These recruiters are almost always affiliated with registered agencies that facilitate MOU migration.

2. Facilitators. In Burmese, there is also a word that is a close translation to the generic word 'agent' or 'representative' pronounced 'kozelay' (ကိုယ်စားလှယ်). In migration rhetoric, this classification is used differently than the English "agent". These individuals facilitate a range of migration services usually for a fee, both as peripheral agents in the MOU process and as central actors in irregular migration pathways. Facilitators are recognised by migrants as frequent service providers within the migration system even though they rarely hold licenses.

3. Brokers. The classification for 'brokers' was pronounced 'pweza' (ပွဲစား). This group is like facilitators in the sense that they offer a range of services almost always for a fee, but they are often more explicitly associated with illegal or dubious business models (e.g., illegal border crossings or document procurement). One informant told us, "a pweza would never call themselves a pweza" even if others recognised them as one.

4. Helpers. The classification for 'helpers' was pronounced 'ajosong' (အကျိုးဆောင်). This is the most informal group of service providers and are the least likely to charge fees for their services. However, these agents are central to supporting migration and this term would only be used to describe someone that made significant contributions to an individual's migration.

5. Smugglers. The classification for 'smugglers' was 'lu maung kho ku thu' (လူမှောင်ခိုကူးသူ). Sometimes migrants might also describe these transporters as 'po saung pay thu' (လူမှောင်ခိုကူးသူ) 'the one who carries'. These transporters are often associated with long-distance illegal routes.

6. Human Traffickers. The last classification for the commonly used term for human traffickers was pronounced 'lu kone ku thu' (လူကုန်ကူးသူ). Unlike the other five terms, migrants did not usually recognise an individual as this classification when they first met them and typically knew them as one of the previous five intermediary classifications first. Since the interviewees

were assigning these classifications, we did not subject the use of this classification to any international definitions, such as the ILO's definition of forced labour. Likewise, it is possible that some actors identified as the other classifications may have been defined as human traffickers according to international definitions, but not by migrants themselves.

The use of intermediary classifications allowed migrants to assign these roles to social contacts and employers that were *acting* in intermediary roles for their migration (e.g., an uncle that arranges work, an employer that helps in document applications). These classifications were not mutually exclusive so a single alter could be assigned to multiple classifications where appropriate.

The definitional boundaries and use of these terminologies, as described in the cognitive interviews, were not always clear or consistent, but the mixed-methods analysis provides more insights into these classifications, including: 1) the frequency of each intermediary classification in the networks; 2) the frequency of the services each intermediary classification provided; and 3) migrants' qualitative descriptions of intermediaries' service model, fees, and reputation.

Analysis

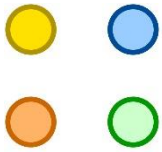
The MMSNA techniques integrated for this study included summary of the structured egocentric network data and thematic qualitative analysis of the network narratives in the interview transcripts. The analysis consisted of sequential and simultaneous mixed methods approaches to describe the network actors (frequency of types of actors and what they did), network structures (size, density, centrality of nodes), and the network narrative (interactions, exchanges, relationship progressions). These approaches utilised links between traditional quantitative network findings and qualitative thematic findings from the migrants we interviewed, which produced richer insights into the dynamic nature of the networks and individual migrants' experiences. Like the data collection, the analysis utilised a bespoke mixed-methods network interface that was specifically

designed and iterated for this study and is detailed in the same paper as the network data collection tool (242). This analysis tool presented a summary of the network by placing the migrant at the centre of the network (demographics, work sector history) and a condensed visualisation of the network alters' demographics and their role in the network. The user ('analyst') could filter between the dynamic stages of a network (e.g., decision to migrate, transit) and easily switch views between networks to conduct both case-based and cross-case analyses.

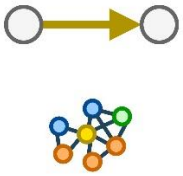
To understand the various pathways migrants used, we looked at the emergence of actors and links in the ego-nets, particularly the way intermediaries were involved at different stages. For this study, the term 'pathway' is used to describe which actors coordinated the migration (e.g., family pathway versus recruiter or 'regular' pathway).

Results

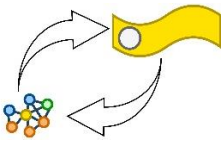
This results section describes the actors, interactions, networks, and pathways, divided into the following sections:



Section 1 describes the Myanmar migrants ('egos') we interviewed and the factors driving their decision-making, as well as the social, intermediary, and employer actors ('alters') and their roles in the migration process.



Section 2 explores the relationships and interactions between egos and alters, the formation of the ego-net structures, and the ego-net dynamics.



Section 3 delves into the bi-directional influence or exchange between migration networks and pathway choices.

1. Migrant egos & Network alters

Migrant 'egos'. The sample of Myanmar migrants (n=81) were nearly equal proportions male (44%) and female (56%), who were, on average, 30 years old (Table 17). They emigrated from a range of areas, most frequently Bago state (33%), followed by Rakhine, Mon, and Irrawaddy states. Nearly half (42%) spoke a second ethnic minority language in addition to the official Myanmar language Burmese. Only three migrants were fluent in any Thai on arrival, but more than half became fluent in either basic (58%) or advanced (5%) Thai after arrival. A minority of the sample had previous labour migration experience (29%) and notably fewer (9%) had any international labour migration experience (6% to Thailand and 3% to Malaysia). However, most migrants had close kin that had migrated internationally to Thailand (74%) or another country (11% e.g., Malaysia, China, Korea) for work.

Table 17. Migrant (ego) descriptive findings – origin, gender, and age

Location (n)	Origin areas (n)	Female % (n)	Male % (n)	(Age Range) Avg./Median
Mae Sot (46)	Bago (20), Irrawaddy (7), Mon (6), Kayin (4), Rakhine (5), Magway (2), Yangon (2)	61% (28)	39% (18)	(19-50) 30/29
Mahachai (13)	Bago (5), Naypyidaw (4), Magway (1), Mandalay (1), Shan (1), Mon (1)	54% (7)	46% (6)	(23-44) 31/30
Phang Nga (20)	Rakhine (5), Tanintharyi (4), Bago (2), Mon (2), Magway (2), Kachin (1), Kawthaung (2), Kayah (1), Kayin (1), Shan (1), Dawei (1)	45% (10)	55% (12)	(18-43) 25/23
Total (81)	Top 4 origins (65% of sample): Bago (27), Rakhine (10), Mon (9), Irrawaddy (7)	56% (45)	44% (36)	(18-50) 29/27

Economic incentive was the primary motivator for migration, but there were nuances between meeting urgent needs (e.g., food, medical bills) and having financial aspirations (e.g., build a bigger house, start a business). The decision to migrate was also often socially influenced, for example, by people the migrant wanted to provide for or be like. In most cases, the motivation to migrate was a combination of both financial and social drivers (see Table 18 for illustrative examples).

Table 18. Drivers for the decision to migrate

	Social influences	
Financial motivations	Providing for others	Wanting to be like others
Urgent needs	"I came alone to earn for my ailing husband's medical bills and my son's milk powder." (PID 510)	"It was a 'do or die moment' for me . . . I wanted to migrate to Thailand because I saw others are better off." (PID 602)
Financial aspirations	"The main reason was for our children's education. I want to send my daughter to a good boarding school." (PID 224)	"We were not better off like others, but we did not have debt either. I just wanted to be better off like others . . . I wanted to get rich . . . I thought migration would help me achieve that." (PID 604)
	"My family has financial problems. We are not like other neighbours. I wanted to send my younger siblings to school, and I wanted to support my sickly father's medical treatment. So, I migrated here." (PID 229)	

*PID = Participant Identification

In some cases, migrants explained that they migrated exclusively for social reasons, such as reuniting with family or joining friends. For example, one

migrant said, “My mother was the first one [who had the idea], she said, ‘Dear, come and stay here in Thailand with me!’, so I did not think about anything else, and I was so keen to reunite with my mother.” (PID 223) In Myanmar, nuclear family support structures often include three generations, and it is common for the middle generation (i.e., the *parent* of the child-parent-grandparent tree) to migrate to Thailand for work while the grandparents assume temporary guardianship of their grandchild. It is common for the children, once in their later teenage years or early twenties, to later reunite with their parents in Thailand and enter employment shortly after arriving, or even have their parents arrange a job for them before they arrive.

Most migrants (78%) reported they at least partially contributed to the initial idea to migrate, compared to cases where the migration was entirely someone else’s idea (20%, Table 19). Amongst the latter, 60% were female and it was usually the migrant’s parents who initiated and implemented the migration plans.

In terms of direct encouragement or discouragement, the largest proportion of migrants said that no one strongly encouraged or discouraged their migration (37%) and equal proportions said they were either encouraged or discouraged to migrate (26%). Ten migrants indicated someone would have “reacted strongly” if they refused to migrate, and the qualitative findings indicate that these were usually either family members or intermediaries during transit. The final row in Table 19 presents two examples of when a migrant was unable to refuse to migrate because of implicit obligations or direct pressures from another person.

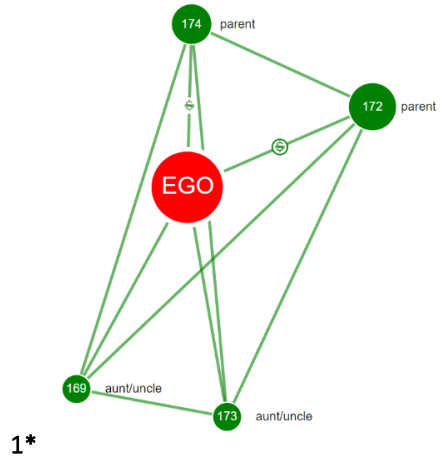
Table 19. Alters involved in the decision to migrate

Whose idea was it for you to migrate?		
"It was my idea to migrate." **33% (27)**	"I had the idea with someone else." **45% (36)**	"It was someone else's idea for me to migrate." **22% (18)**

Did anyone strongly encourage or discourage your migration plans?		
type of influence	**%**	**illustrative quote**
1+ encouragement & 0 discouragement	**26% (21)**	"My sister strongly encouraged me to migrate. She wants me to be better off." (PID 219)
1+ encouragement & 1+ discouragement	**11% (9)**	"My grandma strongly opposed my migration, but my mother didn't give up and forced me to come." (PID 218)
0 encouragement & 1+ discouragement	**26% (21)**	"[My uncle] is a fortune teller. He predicted my migration would be fruitless . . . but I didn't listen." (PID 412)
0 encouragement & 0 discouragement	**37% (30)**	"They told me a bit about migration and the salary, but they didn't encourage me very much, it was my own decision. No one forbid me to go either." (PID 619)

Would someone have reacted strongly if you refused to migrate? If yes, who?

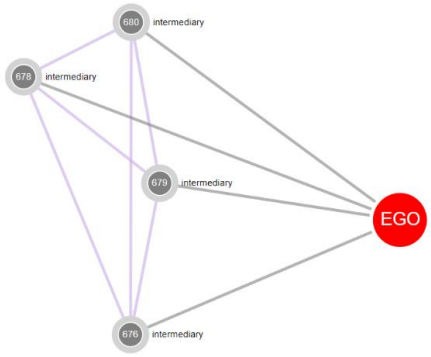
10 egos named **17 alters** in total: **11 family members** (8 of whom also first suggested the migration), **1 friend**, **5 smugglers** – **Two illustrative examples below:**



1*

1. Ego's Aunt was his guardian when his parents lived in Thailand. His parents and aunt had a conflict, so his parents demanded he migrate to join them without giving him any option. **(PID 228, left)**

2. Ego's expected job in Myawaddy was not available when he arrived. Not knowing what to do, he went to a tea shop where he met someone that offered to find him work in Bangkok. While in transit, ego changed his mind, but the group of smugglers used intimidation and violence to force him to continue the journey. **(PID 606, below)**



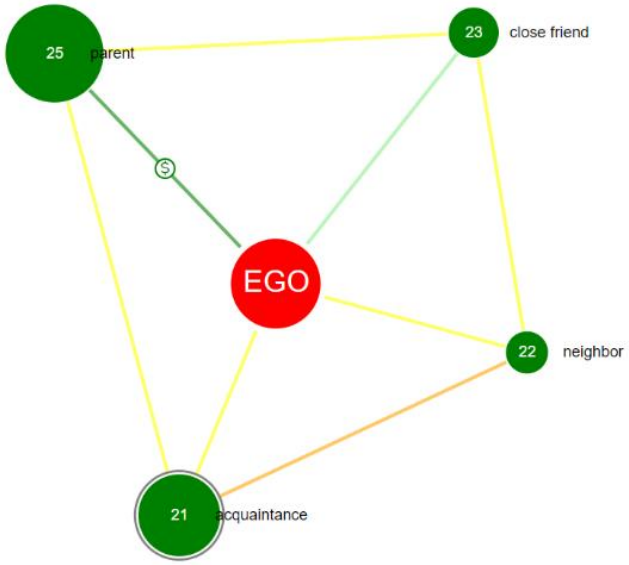
2** (PID 606)

*Ego-Net 1 is filtered to alters involved in the 'decision to migrate'.
*Ego-Net 2 is filtered alters involved in the 'transit' stage.

The individuals who influenced the final decision to migrate were often also involved in assisting with the migration plans. For example, a migrant would explain that they were impressed by a returned migrant's financial gains and then modelled their own migration after the returnee's example. In some cases, the migrant would also directly ask that returnee for advice. Figure 17 illustrates one of these cases where the person who spurred the decision *to* migrate also provided the migrant with advice and connections for *how* to migrate (see Table 20 for Figure legend). Alternatively, when a close social contact motivated the decision to migrate, such as reuniting with kin, then it was usually that same kin who informed or financed the migration plans.

Most often, migrants reported that the migration decision was initiated by an invitation from family or a close friend in Thailand (51%). In many cases, the person that influenced the decision to migrate, for example, the person that encouraged the migration or with whom the migrant was reuniting , was also the person that ultimately shaped the subsequent migration plans (e.g., transportation, destination, employment, etc.). For example, if family in Thailand encouraged the individual to migrate, that individual was usually also the first point of contact for migration planning, or if a neighbour's profit set an example, then the migrant usually chose to go to the same destination. The decisions *to* migrate and *how* to migrate often merged in short periods of time or even single decisions (Table 21).

Alter-21: **acquaintance in Thailand**, fellow villager, arranged transport, housing, and work
Alter-22: **neighbour in Myanmar**, returned migrant, introduced ego to his friend Alter-21
Alter-23: **close friend in Myanmar**, first person ego confided in, encouraged ego's plans
Alter-25: **mother in Myanmar**, gave permission and small loan to migrate



"In my village, we can barely make enough to live. So **[my close friend]** suggested I come to Thailand. **[My neighbour]** had experience working [in Thailand]. He came back to Myanmar, and I saw that he was better off so I got the idea to come and work here like him . . . I envied his situation. I told **[my mom]** that I wanted to earn extra money because we could barely make enough. I told **[my neighbour]** about my desire and he arranged it for me. I said "Brother! I would like to migrate to Thailand, but I do not know anyone there." So, he helped me. He said, "Go and tell your mother that I have **[a friend]** who is working on the fishing boats [in Thailand]. I will ask him to help." I went to tell my mother . . . and she borrowed money for me to migrate. **[My neighbour]** phoned to **[his friend]** and told him, "A youth from our village will come to you because he has financial problems. Please find a job for him." **[His friend]** assisted me. We are from the same village . . . he arranged [the transport] for me . . . He allowed me to stay at his home . . . he provided me with food too . . . He is my sponsor . . . He invited me to work with him at the fishing boat where he worked. . . . I did not know how to work because I was not familiar with the fishing industry, but he encouraged me. He is kind like that." (PID 207)

Figure 17. Ego-net example – social influence on decision to and how to migrate

Table 20. Visual legend for all Ego-net figures

Nodes	Rings	Node-Node ties	Financial exchanges
Ego	Co-migrants	Family	Financed costs
Social Alter	Employer	Close social	Gave short loan
Intermediary/ Employer alter	Intermediary classification (thinner line for 'helpers')	Social	Charged fees
		Acquaintances	Indebted to
		Intermediary-Migrant	Remittance
		Intermediary-Social	
		Intermediary-Social	
		Employer-Employee	
		Co-workers	

Node diameter (size) represents relative 'betweenness' score of the alter to other alters in the ego-net (i.e., how central is that node in the network compared to the other nodes). The diameter of the ego is set equal across networks and does not represent betweenness.

Table 21. Socially-embedded migration decisions

Invited to Thailand by family or friends	Offered job connection by family or friends
"My parents were not worried because I was going to migrate with my aunt. [My aunt] asked me, 'Will you come with me?' . . . [and] she brought me here free of charge." (PID 213)	"My husband's niece invited us to come and work in a papaya orchard. . . . She said we can receive daily income and be better off . . . we were pretty interested in her offer and decided to come here." (PID 409)
"I became an attendant at a Buddhist monastery where I met a friend. He invited me to Thailand, so I came." (PID 216)	"Both of my parents were in Thailand. My Dad works on a fishing boat, and he is the leader of the crew. My dad invited me to work with him." (PID 209)
"My brother, who was already in Thailand, called me to come here." (PID 616)	"My mother was working at a chicken processing factory, so she arranged a job for me before I migrated here." (PID 220)
Requested help from contacts in Thailand	**Employers request new workers**
"My uncles had been in Mae Sot for a long time. . . . I asked them whether I could work in Thailand or not, and they said yes, and I decided to come here." (PID 517)	"[The supervisors] ask their employees whether they have relatives who are willing to work here. When the new employees come here, the boss will go and pick them up from the Thai side." (PID 409)
"I have a cousin who is married to a Thai. I asked for her phone number through a friend. [My cousin] told me, 'If you want to come here, then come! I have a sewing workshop so you can come and work with me. I will come and pick you up at the bank of Mae Sot if you come.' So, I decided to come here." (PID 602)	"My husband introduced me with [the boss] and translated for me . . . If there are vacancies at the gas shop the boss asks my husband to fill them because he is the foreman. I didn't need to pay to anyone, I got the job directly through my husband." (PID 414)

Migrants also described different preferences or conditions for their decisions. For example, some migrants had specific work goals, such as a job that was out of the sun (e.g., factories, hotels, domestic work) or preferring whichever job paid the highest wage. Other migrants were more vocal about destination preferences, for example, going where their social network was strong or somewhere that is relatively close to home. Sometimes migrants described their decision-making in relation to the migration *process* more than the destination or work, for example, using an intermediary with the

lowest fees, getting a passport or work permit before migration, or migrating via people they trusted (e.g., family, vetted intermediaries). Migrants often referenced these drivers (e.g., financial or social factors) and preferences (e.g., employment, destination, or process factors) in relation to why certain actors were involved in their migration. This included a range of interactions, such as using intermediaries that satisfied a preference or avoiding intermediaries that could *not* satisfy a preference or were not needed.

Network alters. There were a range of people involved in individuals' migration, which we grouped into three 'alter types':

1. **Social alters** had a pre-existing social relationship with an ego (e.g., family, friends, neighbours) that motivated their involvement.
2. **Intermediary alters** were more socially distant and their involvement was to coordinate or implement the migration in some way and they were almost always paid for their involvement.
3. **Employer alters** either employed or supervised the migrant at a jobsite in Thailand and these could be the first or subsequent employers.

Most alters were social contacts (64%), then employers (23%), and, lastly, intermediaries (13%). In total, 22% (n=202) of all alters were assigned to at least one **intermediary classification**[19]. Among alters assigned to an intermediary classification (or multiple in some cases), the most frequent were **facilitators** (26%), **brokers** (21%), **helpers** (20%), **smugglers** (16%), **recruiters** (9%), and **human traffickers** (6%). Social contacts accounted for some of the recruiters (3%), smugglers (14%), traffickers (17%, small-n = 18), facilitators (24%), and brokers (28%), but most of the helpers (68%). The remaining intermediary classifications were almost entirely assigned to

[19] Refer to the Methods section for an explanation of how the use of the intermediary *type* and intermediary *classification* differed in this study design, as well as descriptions of the different intermediary classifications (facilitator, broker, recruiter, smuggler, helper, human trafficker).

intermediary alters, except a small number of employers assigned as traffickers (6%), facilitators (5%), helpers (4%), brokers (4%), smugglers (4%), and recruiters (3%).

Nearly half (42%) of the alters with at least one intermediary classification were assigned multiple intermediary classifications, usually because they were involved in more than one step in the migration process. The most frequent combination of intermediary classifications represented were **facilitator and smuggler** (18%), **facilitator and broker** (10%), and **human trafficker and smuggler** (9%) (Table 22).

Table 22. Intermediary classification combinations

	Recruiter	Facilitator	Broker	Helper	Smuggler
Facilitator	4%				
Broker	5%	10%			
Helper	4%	7%	7%		
Smuggler	1%	18%	5%	8%	
Human Trafficker	0%	8%	4%	3%	9%

The denominator is the total number of alters with 1+ intermediary classification (n = 202). In a minority of cases, some alters were assigned 2+ classifications, these alters combinations would be counted in multiple cells of this table.

Alter involvement varied across migration stages and individual ego-nets. For example, some alters were involved in multiple stages (e.g., mother encouraged *and* financed the migration), or, alternatively, some steps involved multiple alters (e.g., mother *and* neighbour both contributed to financing the migration). Finally, in some cases, no alters were involved (e.g., migrant had savings to cover the migration expenses).

Social alters were most often involved in general migration planning, which usually included thinking through the high-level plans for when and where to go or how to get there (21%), arranging transportation (14%), and arranging work (14%), but never arranged work contracts and rarely arranged immigration documents before (4%) or after (2%) transit (Table 23). Employers were usually only involved during the employment stage at destination, including helping migrants arrange immigration documents

after arrival (13%) and sometimes arranging accommodation at destination (9%).

In contrast, intermediary alters were involved across all stages of migration and most often helped with general migration planning (42%), arranging transport (41%), and/or executing the transportation plans (52%).

Shifting the focus to intermediary *classifications*, which includes social actors or employers acting in intermediary roles, the different intermediary groups had distinct patterns of involvement. For example, facilitators and brokers were generally involved in similar ways except that the facilitators more often played a role in general migration planning (51% versus 42%). Not surprisingly, recruiters more often arranged the destination (52%) and pre-departure documents (45%) compared to all other intermediaries. A similar proportion of recruiters (45%) and helpers (40%) arranged work placements. Importantly, intermediaries were rarely involved in arranging work contracts or documentation post-arrival at Thailand.

Table 23. Alters role in the migration process

alter Type or Intermediary Classification	N	Destination	General Plans	Pre-departure Documents	Pre-departure Contract	Transport Plans	Transport Execution	Accommodation	Work	Post-arrival Documents	Post-arrival Contract
All alters	903	11%	19%	6%	1%	15%	12%	11%	13%	6%	0%
Social	575	11%	21%	4%	0%	14%	6%	12%	14%	2%	0%
Intermediary	122	25%	42%	16%	11%	41%	52%	13%	25%	12%	2%
Employer	206	0.5%	0.5%	4%	0%	2%	2%	9%	4%	13%	0.5%
Recruiters	29	52%	34%	45%	31%	4%	28%	10%	45%	10%	0%
Facilitators	86	31%	51%	17%	8%	45%	47%	17%	33%	13%	2%
Brokers	69	33%	42%	20%	7%	45%	46%	23%	32%	10%	1%
Helpers	72	35%	43%	14%	4%	43%	25%	40%	40%	7%	1%
Smugglers	52	23%	48%	4%	2%	48%	63%	10%	21%	8%	0%
Human Traffickers	18	39%	56%	6%	0%	33%	56%	11%	28%	6%	6%

This table presents row percentages. Because alters can have multiple roles these percentages do not add up to 100%.

Table 23 provides a high-level comparisons of intermediaries' roles in migration. However, this study aimed to go beyond these categorisations to explore the nuances of *how* recruiters, facilitators, brokers, helpers, and smugglers operate in these roles, including their **services**, **fees**, and **reputations**.

Next, this paper presents thick narratives of intermediary involvement using integrated thematic qualitative analysis alongside case-based and cross-case comparison ego-net visual analysis. The description of each intermediary classification is accompanied by a joint-display (network visual alongside narrative) to illustrate a typical narrative that involved that type of intermediary.

1. Recruiters

Recruiters are licensed intermediaries who are usually affiliated with registered agencies in Yangon, Myawaddy, Magway, or, in the case of Thai recruiters, Mae Sot or Bangkok. In total, there were 29 'recruiters' (9% of all intermediary classifications) across 18 ego-nets (22% of total).

Recruiters' services often included arranging the destination (52%), pre-departure documents (45%), and work placements (46%). In most cases, recruiters were directly involved in coordinating the MOU procedures (i.e., legal migration), but in some cases, their job was to recruit and refer prospective migrants or assist migrants in preparing their passports before arriving at the agency (i.e., who other research describe as 'sub-agents' (91)). Recruiters were responsible for processing MOU applications and matching workers with Thai employers.

Recruiters' fees varied, but migrants reported paying two to ten times the legal maximum ($150 USD) either upfront, on arrival, or through salary

deductions. In some cases, migrants said they could not distinguish between 'service fees' and other expenses (e.g., passport, transport). One migrant said, "[the recruiter] was not specific about the cost . . . but I knew that they charged high fees to migrants." (PID 406) Multiple migrants said that recruiters instructed them to lie to government officials about the fees, for example, ego 806 explained:

> "When we signed our contract in Yangon, the recruiters made us lie about the fee to the authorities. They said we should tell them that it was only one and half lakh ($150 USD) . . . I knew something was fishy, but I did not dare to ask about it and I was content with the fact that they arranged the migration for me." (PID 806)

Migrants almost always knew that, on paper, these exorbitant costs were illegal, but in practice they accepted the costs as part of the process.

Recruiters' reputations were repeatedly, almost verbatim described as: "There are both good and bad recruiters." (PID 218). This was said by many migrants regardless of whether they used recruiter services. Some migrants expanded to give examples of 'bad' or 'good' recruitment, but their evaluations were almost always descriptions of final outcomes (e.g., the recruiter cheated you versus they got you a good job) not assessments distinguishing between the value of services that might lead to these outcomes. Migrants also described several risks or uncertainties in using recruiter services, especially the risk of being 'cheated'. Cheating, again, included exorbitant fees, but also unmet expectations of the job or working conditions. Egos 802 and 218 described their perceptions of these deceptive practices:

> "Most recruiters are cheaters, and it is costly to come with them . . . you are more likely to have problems too." (PID 802)
>
> "I heard that there are good recruiters and bad deceiving recruiters, some recruiters deceive in the MOU [process], while others will give you fake passports, but not all recruiters are bad ones." (PID 218)

Some of the respondents, such as Ego 412, described first-hand accounts of recruiter deception:

> "[The recruiters] told me that we would have to work at a construction site, but when we got there the working condition was very scary and it was different from what they had told us." (PID 412)

Importantly, although recruiters were often described as costly and unreliable, they were seen as an essential part of legal migration. Ego 416 explained that she did not believe she could travel without the help of a recruiter:

> "Most people do not know how to begin their MOU process so they must use the recruiters for that. . . . If you do not use the recruiters, you will be very confused. . . . If you use the recruiters, you have to pay but you do not have to go through the process by yourself. . . . [even if] the recruiters do not treat us politely." (PID 416)

Many migrants who used recruiters said they expected to be protected by the more formal processes. Some even paid the exorbitant fees *knowingly* in exchange for assumed protection. Two migrants that faced employment challenges after arrival due to unfair recruitment practices explained that the formality of the process gave them a sense of guarantee even when they saw early signs of unfair practice:

> " . . .our logic was that if we signed officially in [the town hall], the recruiter would not dare abuse us." (PID 804)

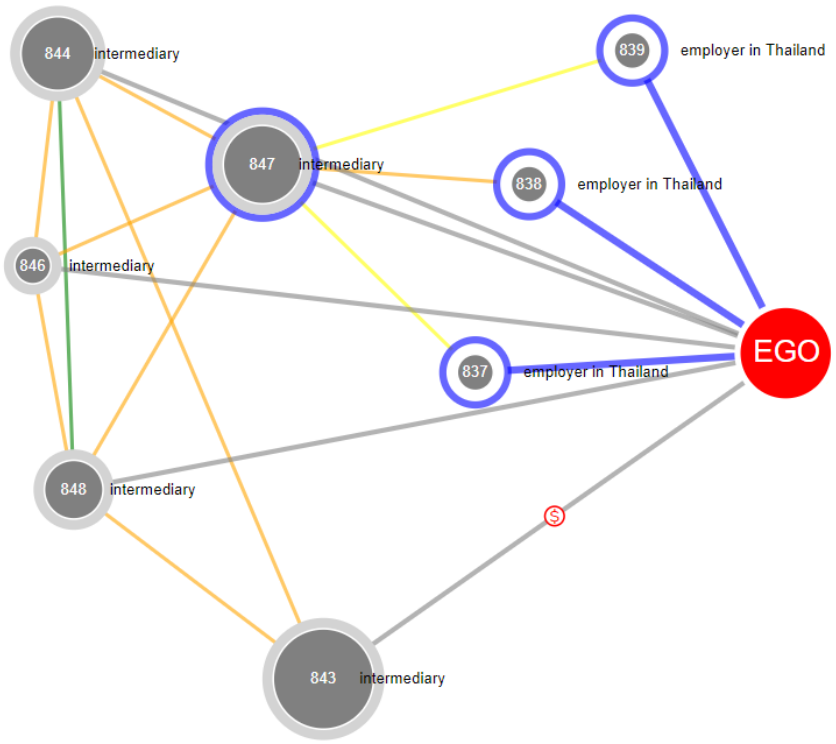
> "We thought if we migrated to Thailand through the MOU system that we would not get into trouble. . . . We thought if we had the official documents, we would not be in trouble like this." (PID 803)

Many qualitative accounts indicate pervasive recruitment abuses in the MOU pathway. Nonetheless, when asked what a migrant can do to ensure they migrate safely, migrants seem to indicate it is a matter of luck:

> "If you meet with a good one [recruiter], your migration will be smooth, and you will get a good job in Thailand. . . . If you run into a

bad one [recruiter], you will only lose your money, and all will be wasted." (PID 409)

Migrants indicated that there was no guarantee of outcomes when following the legal MOU procedures. Figure 18 presents a narrative for one migrant that experienced unfair recruitment outcomes in an MOU pathway.



Swe Nu (not real name, PID 805) went to the Magway passport office to apply for her passport and in the process was introduced to a **facilitator** (**Alter-843**) that had connections to a **recruiter** couple in Yangon (**Alter-844** and **Alter 848**). Swe Nu was eager to get to Thailand, so she agreed to accept their help and her passport was sent directly from the office to the Yangon agency. The **recruiters** called her to Yangon to sign the contract for a seafood processing job. The **facilitator** arranged her transportation. Swe Nu paid them ~700 USD for her and her husband's migration. Swe Nu noticed the **employer's** name on her contract was changed to "general worker", but she did not raise an issue. The **recruiters** sent them from Myawaddy to Mae Sot to be picked up by two other contacts that would transport them to Bangkok**.** After arrival, Swe Nu had many problems, such as jobsite changes, unmet expectations, and unpaid wages.

Figure 18. Ego-net example – introduction to recruiters

2. Facilitators

Facilitators are informal intermediaries that migrants rely on for a range of migration services. In total, there were 86 'facilitators' (26% of all intermediary classifications) described across 43 ego-nets (53% of total).

Facilitators' services most often included arranging general migration (e.g., high-level plans for when, where, how to migrate) (51%) and transport (45%) plans for migrants. Nearly all the facilitators were either only functioning as intermediaries or were acquaintances, not family or close friends. Facilitators are not licensed agents, but there was often some formality to how they were perceived by communities and other intermediaries. Facilitators were commonly the first points of contact for migrants that wanted to plan their migration and therefore facilitators had a strong influence on the migrant's trajectory and subsequent migration decisions (e.g., transport, documentation, work placement) even if they did not directly manage each step. Figure 19 presents one example of a migration planned by a facilitator. Facilitators usually offered planning support along with one or more other service (e.g., arranging passports, accompanying migrants in transit). Migrants described different ways that facilitators advised migration plans or offered support:

> "The [facilitator] advised my migration. He said that there are plenty of jobs here and I would definitely get documents as soon as I arrived here. . . . After my money ran out, I borrowed money from [him]. He has been here a long time. His contact arranged my transportation." (PID 803)

> "[The facilitator] stayed in our neighbourhood, she worked in this factory before [me]. . . . I went and asked her about migration. She said that because I can sew, I do not need to worry about getting a job. She explained the job options. She introduced me to the manager . . . I did not have documents at that time, and she warned me not to go outside because the police might arrest me . . . [she] chose the destination for me." (PID 503)

Facilitators regularly introduced migrants to other intermediaries (e.g., smugglers) or job connections (e.g., other migrants already in Thailand):

> "[The facilitator] and his wife arranged the transportation for me. He did not know the boss. [He] told the broker to find the jobs for us." (PID 219)

> "[The facilitator] contacted her brother for us. . . . he helped me get the passport in Yangon." (PID 807)

In some cases, facilitators identified migrants for recruiters or arranged the peripheral logistics to the MOU process (e.g., accommodation in Myawaddy during wait times), but this was more akin to freelancing than being an established or licensed agent in the MOU network.

Facilitators' fees were often less than the recruiters' fees for the MOU process, depending on which services they offered, and some facilitators did not charge any fees. Those that did not charge fees were either acquaintances offering voluntary help or MOU 'freelancers' that migrants did not report paying anything to directly, but likely received payment from the recruiters. In some of the cases where facilitators were also fellow migrants, they might coordinate the financial exchanges between a migrant and the smugglers, and either take a small fee for themselves or add their own expenses onto the costs charged to the migrant (e.g., they get a 'free ride' for having brought customers). Facilitator fees, like recruiter fees, could also be charged to employers on arrival and deducted from wages later. Migrants described a broad range of how these financial exchanges worked in different migrations, for example:

> "[The facilitator] said he will transport us to Thailand and arrange the jobs for us. . . . We had to pay [the facilitator] for his help in the migration and it was about 20,000 Kyats (~$15 USD) and we had to cover his transportation expenses too." (PID 515)

> "Yes, some people used facilitators . . . [but] then when they arrived at Thailand, they received less than the agreed salary because of the fees. I heard [facilitators] squeeze money out of migrants." (PID 417)

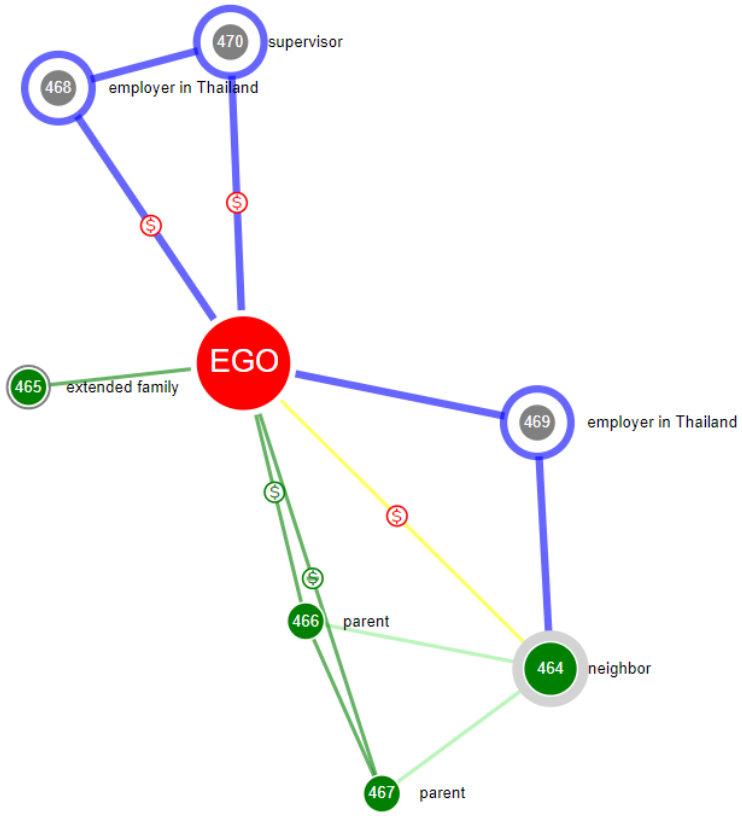
Facilitators' had reputations for being knowledgeable about migration, usually from their own previous migration. One migrant described her facilitator as a leader among the migrants:

> "The [facilitator] was a leader in our migrant group and he led us in everything. He is my fellow villager. He has been to Thailand, so I relied on him and followed with him." (PID 219)

Like recruiters, migrants said that some facilitators, specifically those charging high fees, could not all be trusted. Some migrants said they paid facilitators for help with documentation, but were cheated:

> "I paid her 9,000 Thai Baht but I did not receive the document and she did not update me on the progress, and she delayed again and again . . . So, I did not contact her anymore and I consulted with my boss about suing her in court." (PID 620)

Facilitators who gave general advice, helped with planning, or offered valuable introductions were rarely criticised, likely because they rarely charged fees. Facilitators were seen as critical intermediaries in most of the pathways used in the labour migration system, even in the highly regulated MOU process.



Mar Kyi (not real name, PID 503) had a neighbour (**Alter-464**) who was her father's friend. This neighbour was the **facilitator** for Mar Kyi's migration. She arranged the plans, transport, and work at destination. She set Mar Kyi's expectations around the migration process and situation at destination. She gave Mar Kyi a discount on her usual facilitator fees, because of her friendship with Mar Kyi's father.

Figure 19. Ego-net example – facilitator embedded in family network

3. Brokers

Brokers are unlicensed intermediaries that offer a range of highly informal services for a fee. There were 69 'brokers' (21% of all intermediary classifications) across 40 ego-nets (49% of total). Nearly two-thirds of these brokers were exclusively intermediaries and one-third (28%) were social alters, including family and friends.

Brokers' services often included planning (45%) and executing (46%) transport, but beyond these trends, migrants described a broad range of broker characterisations. One migrant said, "There are different types of brokers. A broker who transports people, a broker who finds people jobs,

there are several." (PID 205) See Figure 20 for an example of one network that included a broker that arranged border crossing and temporary entry documents. While brokers' services varied, they were almost always involved in irregular migration pathways.

Because many migrants choose to enter Thailand illegally, brokers were often described as 'essential' to migration. One migrant said, "I did not have the required documents, so I had to use brokers." (PID 228) Migrants described many experiences of being transported by brokers:

> "[The broker] helped me for a fee. He is a ferryman . . .. those ferrymen arranged everything for the passengers if you chose to ride in their boats . . .. When I arrived to Kawthaung, my aunt introduced me with him . . .. He arranged everything for me until I arrived at Thailand." (PID 229)
>
> "I just came and passed the border line in simple way. I had to pay all the money to a broker as soon as I arrived at Yangon." (PID 211)

In some cases, brokers helped migrants get fake documents or stamps in their documents to lengthen their stays. While descriptions of facilitators also mentioned some document processing, this was more often described as a role played by a distinct kind of 'document broker'. Migrants explained different scenarios where they needed brokers help with documentation processes on both the Myanmar and Thai side:

> "When I arrived here, we had to extend our visa and the [broker] arranged it for me . . .he is Thai and he worked at my mother's factory . . . I had to pay 1 Lakh to him (~$75 USD)." (PID 221)
>
> "Most migrants do not know the document process, so they have to use the broker. . . . They will use the broker for the card extension or passport stamp." (PID 213)

Often, brokers helped with a single, discrete step. For example, brokers would *only* transport to destination or *only* help with a long-term document, unlike facilitators who often helped with the full trajectory planning and coordination across intermediaries, including the range of services offered

by brokers. The exception was that brokers who were also social contacts were often already in Thailand and helped to broker migrants' entry into work through their connections. In these cases, the broker sometimes helped coordinate more general plans in relation to that specific job (i.e., transport to that jobsite, documents for that employer), but not offering transport or documentation services more generally to other migrants. Brokers that also helped arrange work were usually classified as 'facilitators' as well, indicating a spectrum of services in which it appears facilitators cover a broader range of the migration steps than brokers.

Migrants explained that brokers were usually migrants before becoming brokers:

> "[The brokers] were migrants like us in the past and they became familiar with the migration process. They became [brokers] because it is easy money." (PID 806)
>
> "I think when [migrants] live here for a long time and they begin to know the migration process very well then they will become a [broker]." (PID 213)
>
> "Most brokers have been [to Thailand]. If they are a broker for [Thailand], they have been here. If they are brokers for Malaysia, they have been to Malaysia." (PID 217)

Brokers almost always charged fees, except for some social contacts acting as brokers. The fees varied by which service (e.g., documents, transport) they were offering. Even though many migrants knew these fees were illegal they described these transactions to be a frequent occurrence between brokers and migrants:

> "The broker helped us because he got money. . . . so, it was mutual gain." (PID 514)
>
> "The [brokers] always take money from us and they do not obey [the law] because they are money-driven." (PID 410)

Respondents that used brokers for illegal transport paid in the range of $300 USD. Broker fees for documentation services tended to be lower, but these payments were usually required upfront and therefore were riskier investments compared to transport fees, which were often partially paid on arrival by the migrant or their employer. Migrants explained the varying fees and what services they received:

> "I had to spend a lot. When I came to Thailand, I had to pay more than 10,000 Thai Baht (~$330 USD) for my trip." (PID 217)
>
> "He said, 'Give me only 2,000 Thai Baht' (~$65 USD) and I gave him 2,000 Thai Baht along with my ID and four photos. . . . He said I must wait 3 days to get the documents, but I did not [get the documents]. . . . When I asked him why, he said it was because I do not have a Myawaddy Household list . . . I lost my money." (PID 403)
>
> "I heard that [document brokers] cheat people and you cannot trust every facilitator. The first time I went to the embassy it was not OK. I did not understand the visa processes . . . I thought it would be better if I used the [broker]. I also thought it would not hurt to use a little money on that." (PID 227)

Migrants said the lucrative nature of brokering was appealing, especially to migrants with specific knowledge to share from their own migrations.

Brokers' had reputations for being the 'illegal actors'. Migrants also said that they had heard stories of brokers that trafficked migrants or smuggled them via extremely dangerous routes. However, even with this knowledge, many migrants still used brokers' services when they deemed it necessary. Often migrants knew the general route to destination, but the specifics of how they would transit were unknown in advance. When possible, migrants tried to use brokers that had been recommended by others or, in some cases, used social contacts as one alternative to brokers, or even found ways to navigate migration without a broker:

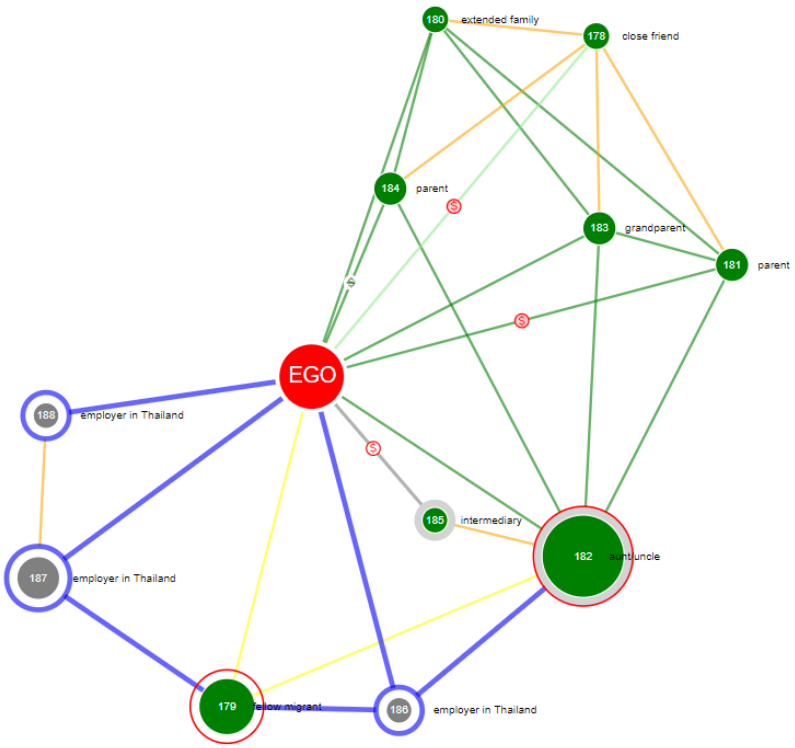
> "My friend's mother introduced me to him, she said that her daughter, my friend, also went with him, and he is trustworthy . . .I

> did not know anything about [the broker], I thought if that person who migrated before me with him arrived safely, I will be fine too." (PID 221)
>
> "I would not think to use a broker if I needed a job. As far as I hear, there are not many brokers who are good. Instead of contacting them, I think I would just contact my relatives I know." (PID 205)
>
> "I do not trust the brokers, so I applied for the job by myself. I would not have the chance to communicate directly with the employer if I used a broker. . . . If you use the broker, you will not know your rights. You can know your rights if you talk directly with the boss." (PID 507)

But, again, brokers were often described in the binary of good and bad:

> "I heard that there are both good and bad brokers and if we encounter the bad one, we will be unlucky." (PID 228)
>
> "[The brokers] persuaded people to go with them. Some [brokers] are trustworthy while others are liars and cheaters, and they only cause problems." (PID 413)
>
> "When I was in the village, I heard about the brokers and that there are both good and bad brokers, the bad brokers will traffic you to Thailand, so I was scared, and I wished to meet with the good broker." (PID 220)

Migrants often implied that whether they met a good or bad broker was not within their control.



Kyi Kyi (not real name, PID 229) was migrating to Thailand with her **aunt** (**Alter-182**) who had migrated to Thailand frequently. They travelled to Kawthaung and met up with a **broker** who was also a ferryman at the port **(Alter-185).** Her aunt said he was her friend and trustworthy and helped many other migrants. First, he arranged documentation for them to enter Ranong and he also transported them across. Kyi Kyi said these were illegal documents and not the official ones. Because this ferry trip was illegal, the **broker** asked for 1,000 Thai Baht (~$33 USD) which is ten times the normal 100 Thai Baht crossing fee between Kawthaung and Ranong. Kyi Kyi said her migration would not have been possible without the help of this broker.

Figure 20. Ego-net example – broker that helped transport via immigration checkpoint

4. Helpers

Helpers are individuals who provide different types of informal support for migrants at any stage of their migration and do not usually charge any fees. There were 72 'helpers' (22% of all intermediary classifications) across 39 ego-nets (48% of total). Two-thirds of all helpers were social alters.

Helpers' services, like facilitator services, often included general migration (43%) and transport planning (43%), but more so than facilitators, helpers also often arranged work (40%) and accommodation (40%) at destination. Helpers do not have a set service since their involvement was usually either highly relationship-specific (e.g., a family member arranging another family member's migration) or a chance encounter in response to unplanned events (e.g., a migrant faces a challenge, and a stranger or acquaintance offers to help). For example, Ego 510 described a helper she met in transit:

> "We were having lunch at the restaurant near the Clock Tower of Hpa An and we started chitchatting and she asked me, 'Where are you going? Where will you work in Thailand?' and she told me that her boss needed a [domestic worker] and asked me whether I would like to go with her or not . . . and I decided to go with her." (PID 510)

Other helpers were parents or extended family that were in Thailand. Helpers were not simply 'people that helped' but were individuals that contributed in a significant way to a migration trajectory. Migrants described many different alters as helpers based on the valuable support they offered:

> "That Burmese guy who rescued us from the landlord when we were working at the ice cream factory was our helper." (PID 805)
>
> "I did not have money so [my husband's friend, the 'helper'] came and picked me up and I did not have work, but he let me stay at their house for a while and he also searched for a job for me." (PID 413)
>
> "[The helper] helped us through her contacts and it was for free." (PID 412)

Helpers did not usually charge fees. They may have even paid for some expenses or given loans, as well as carried the costs of accommodation or food for migrants when they first arrived. Migrants said they would show their gratitude by paying the helpers back later or giving them gifts of appreciation. Migrants described helpers as those that have support out of kindness:

> "[He] helped me with everything. He did not charge me a cent and he helped me with kindness. He is my neighbour too. . . . When I went back home, I gave him a present, like a sarong or fruit." (PID 207)

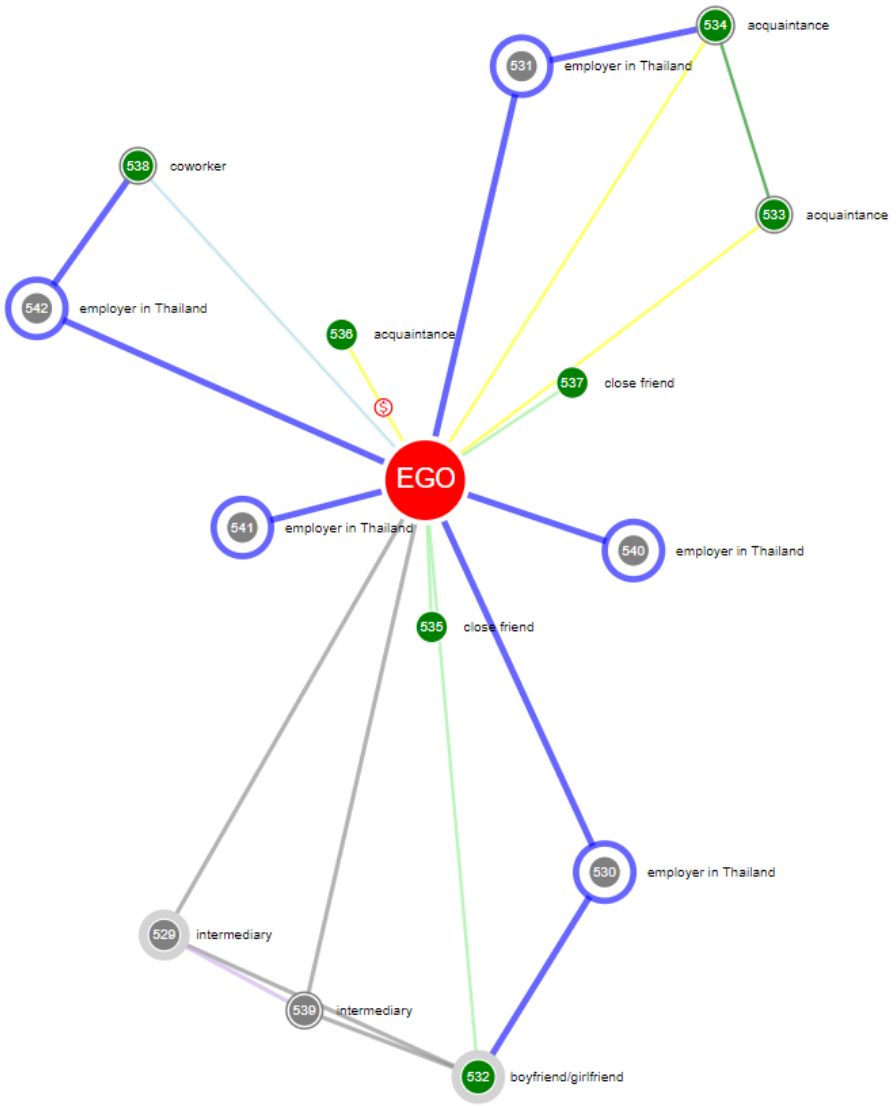
> "He helped me arrange the travel documents. He told me what I needed to do in the migration. . . . He did not charge me. He helped me with his kindness." (PID 227)

> "My aunt is very helpful, and she indeed helps others without charging them, she is a volunteer for them, and they are grateful for that, and they usually come and pay respect to her with a gift, including cash." (PID 608)

Helpers had reputations for being selfless in comparison to other types of intermediaries that by comparison were only motivated by money:

> "There are those who help you without self-interest, they are [helpers] while the recruiters are money-driven." (PID 805)

> "A helper is helpful to you without self-interest, but the broker only cares about money." (PID 803)



Kyaw Nang (not real name, PID 511) was stranded in a small Myanmar border town after the group he was traveling with abandoned him. Kyaw had loaned his travelling companions all of his money, so he did not know what he was going to do. A local shop owner (**Alter-534, 'helper'**) asked him if he needed help and offered to take Kyaw to Mae Sot where the shop owner's sister (**Alter-533**, second 'helper') lived. When Kyaw arrived in Mae Sot, the sister helped him get a job at the factory where she worked. Kyaw said these two new acquaintances were the **helpers** that made his migration possible. They did not charge him any fees for their help.

Figure 21. Ego-net example - unexpected helpers

5. Smugglers

Smugglers are individuals who provide transport to and within Thailand, almost always for irregular migrants and usually along long-distance routes. There were 52 smugglers (16% of all intermediary classifications) across 25 ego-nets (31%).

Smugglers' services usually included general (48%) or transport (48%) planning and most of the time included executing the transport services (68%). In some cases, where there were multiple smugglers, one would do the coordination and the other(s) would complete the transport.

While social alters, facilitators, and brokers also offered transportation services, we noted the distinction between smugglers and these other actors is that smugglers rarely had any pre-existing social relationship to the migrants and the journeys they coordinated were almost always long, dangerous, and illegal, whereas the journeys other actors coordinated were varied in these respects.

Smugglers almost always offered transportation to distances far beyond the border areas, for example, to Bangkok or Phang Nga (in southern Thailand) that migrants could often not get to without help. Most of these routes involved dangerous treks through the jungle or mountain areas known as 'the jungle way'. Other smugglers offered car transport on major highways, but the migrants needed to be hidden in tight spaces because they were undocumented. On the jungle way there was the risk of military surveillance and on the highway, there were police check points where they searched truck cargo. For many migrants, smugglers were a means to get to the destination of choice at which point others (social contacts, intermediaries) arranged the rest. Often migrants explained the choice of these farther destinations was because they already had family there or they thought the wages would be higher, especially in Bangkok. Figure 22 depicts multiple migrations where a migrant used smugglers' services. Migrants described

the various ways they were transported by smugglers, usually in large groups, and often facing very serious hazards and violence:

> "[My niece] sent a smuggler to pick me up . . . I was afraid, but we had many fellow migrants with us. We had to ride together as 4 passengers on one motorbike and we had to travel by the jungle road. In cars, they [transported] 20 migrants per car so it was very crowded, uncomfortable and suffocating for the passengers." (PID 616)
>
> "They told us to be quiet and sit tightly without making any sound because sometimes, the police will poke [the cargo] with iron sticks to examine whether any humans are being smuggled inside. Migrants even died because of that in some cases." (PID 509)
>
> "At first, I crossed into Myawaddy with a boat, and I got into the pickup truck there and then I walked . . .it was about 10 days. What an arduous journey! . . . The Thai soldiers chased after us with dogs. It was very scary, and we had to run for our lives. . . .Sometimes, we ran out of rice ran and we had to squeeze water from the banana tree, and we had to eat the roots when we were hungry. . . . After those terrible ten days, finally, we got into a car. We finally arrived at Bangkok." (PID 516)
>
> "The smugglers reacted strongly when I refused to continue my journey. . . . A guide beat me up for refusing and I wanted to strike him back, but there were three or four other smugglers around us so I could not do it. . . .We had to stay in that forest for two days. . . . I guess the forest is around Bangkok . . . We had to hide in the bushes, and they guarded us with guns." (PID 606)

Smugglers' fees ranged from approximately $150-450 USD, depending on the route and length of time in transit (e.g., time that they had to host or feed migrants). Partial fees were usually expected up front to guarantee the journey and remainders were paid on arrival. There were a few cases where migrants said they paid the Thai police to act as smugglers to transport them back to the Mae Sot-Myawaddy border area under the false pretence of 'deportation' to protect them from actual deportation or arrest during their

undocumented return journeys. The migrants described the different fees they paid, for example:

> "His main responsibility was to deliver me to my parents, and he got his service fee after that. The fee is between 350,000 - 400,000 Burmese Kyats (MMK) (~$300)." (PID 204)

> "I travelled by bus from Mawlamyine to Kawthaung and the smuggler who my uncle sent came and picked me up there and I had to pay 5,000 THB to him (~$165 USD)." (PID 509)

> "I had to go back [to Myanmar] with the smuggler. This time the police arranged the transportation for me with their police car and I had to pay 3,700 THB (~$120 USD) for their services. They sent me back under the pretence of arresting me." (PID 510)

> "Yes, I travelled from Myawaddy to Dawie first and then I walked and crossed into Thailand with the smugglers. We had to hide if we crossed paths with any local Thai and we travelled by car to Bangkok later. . . . the total fee was 7,000 THB (~$230 USD). My brother paid 5,500 THB in advance and I paid the rest with my wages." (PID 512)

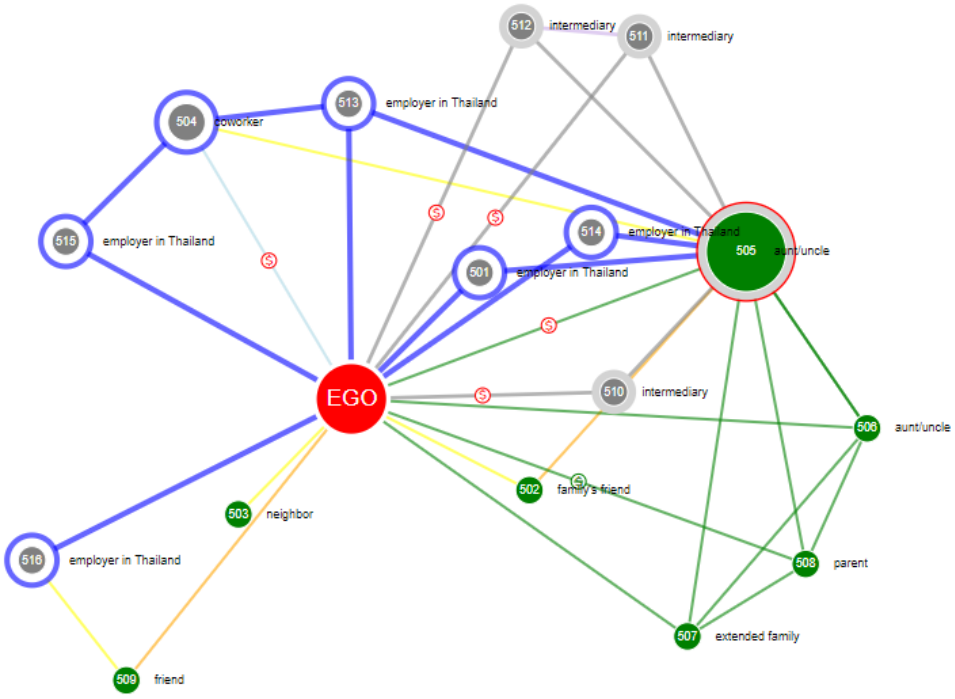
Smugglers had reputations for being a risky choice, primarily because the routes were dangerous and policed. Occasionally, migrants attributed risks to smugglers directly, but there was not the same broad dichotomy of them being good versus bad since all smuggler-facilitated transit was accepted to be dangerous and uncertain.

> "Yes, I heard what others said . . . They said if you go the jungle way you will get arrested and they will throw you into prison if you are unlucky . . . but I like to take risks, so I was not afraid to migrate. . . . The smuggling way is very dangerous, and you cannot trust the transporters. . . . I did not trust him." (PID 617)

Less common to smugglers more generally, one migrant said their specific smuggler was concerned for their safety, in recognition of the dangers inherent to these routes:

> "[That smuggler] was [my niece's] husband's uncle and they are religious people so we can trust them . . .. It was like that . . .. [That

uncle] lost one of his relatives because of an accident in [migration] transportation and he decided to try to implement safe migration for people. . . .Other carriers are not trustworthy, and I could not speak Thai so they can deceive me." (PID 616)



Tin Htwe (not real name, PID 509) was invited to migrate by his **uncle** (**Alter-505**) who had migrated to Thailand for work many times. Htwe migrated alone to Myawaddy and stayed at his uncle's friend's house. The next day Htwe crossed the river illegally by boat and went to meet the **smuggler** (**Alter-510**) that would guide Htwe via the jungle way to Bangkok to meet his uncle for work. Later, Tin Htwe returned to Myanmar for a short time and again migrated to Thailand to meet his **uncle** who had moved onto new work in Phuket (southern Thailand). This time Tin Htwe travelled alone to Kawthaung, Myanmar's southern border crossing to Thailand, to meet a **smuggler** (**Alter-511**) who transported Tin Htwe across to Ranong and then onto Phuket. This smuggler then transferred Htwe to another **smuggler** (**Alter-512**), who was an off-duty police officer that transported Htwe to the construction site outside of Phuket where his **uncle** was working and had arranged a job for him. Tin Htwe's uncle knew all three smugglers and arranged the transportation for both migrations.

Figure 22. Ego-net example – smuggler coordinated migrations

Other alters

Table 24 describes a selection of other non-social actors that migrants described who did not easily conform to the intermediary classifications.

Table 24. Other non-social alters in the ego-nets

Type	Description	Illustrative quote
Transit scouts	Guides positioned along illegal transit routes that accompanied migrants for short distances (e.g., tribesmen, jungle scouts).	"We met with Hmong ethnic people, and they helped us and guided the way." (PID 516)
Interpreters	Individuals that speak Burmese and Thai that helped migrants navigate Thai systems or were based outside of key points of interest (e.g., translated in the MOU process, police interactions, immigration procedures) to identify migrants that needed their services.	"The interpreter from Mae Sot jail said 'Oh, if your document expires, I can extend it for you. She came to my house and asked for payment. She said she would need to go to Bangkok . . . so I gave her money for the transport as well, but I can't get contact with her now." (PID 614)
Supervisor 'gatekeepers'	Myanmar migrants promoted to management roles acted as 'gatekeepers' for other migrants looking for jobs. They often took a 'recruitment fee' and sometimes translated for their employers.	"[My cousin] introduced me with Cho who is the manager of the site. . . .he offered me a job, but I had to pay 500 Thai Baht (~$17 USD) to him." (PID 502)
Remittance runners	Myanmar migrants that did regular circular trips and offered to transfer cash or letters from Thailand to Myanmar. They make regular trips between places like Mae Sot and origin areas	"[My neighbour] is honest . . . She goes around the factories and collects migrants' transfer money . . . she delivers that money to their parents . . . She does not charge a fee. You can give her as you like . . . She is a good-minded woman." (PID 605)
Document clerks	Administrative clerks that worked directly for employers to coordinate new documents for undocumented workers' process passport or work permit applications after they arrive.	"There are clerks in this factory . . . They make the document applications for us." (PID 406)

In summary, the portrayals of the actors in these migration networks highlight the broad and nuanced range of influencers and intermediaries present across different trajectories and stages. There were not conclusive findings of which actors were 'risky' or 'protective', although there were some distinct patterns of services, fees, and reputations that highlight why migrants might choose one intermediary over another.

2. Ego-Net Links & Structures

On average, each ego-net (n=81) had 11 alters with 20 links between them, 1.5 intermediaries, and 2.3 employers. This indicates that it was common for migrations to involve multiple intermediaries and for migrants to change employers after arrival. Family members played significant roles in the migration process (39% of ego-alter links, 43% of alter-alter links) and were often present at both origin and destination. Employer-employee relationships were also common among the alter-alter links (15%), as many migrants found work through their social networks at destination (i.e., friends, family, or acquaintances at destination were often linked to the same employer as the migrant). The presences of links between social and non-social actors (i.e., intermediaries and employers) demonstrated how enmeshed the social and intermediary networks are in the Myanmar-Thailand corridor. See Appendix 6.2 for more detail on ego-net links.

In some cases, an intermediary only facilitated one discrete step in the migration process with no reference to other actors (i.e., an 'isolate' ego-net node). A single network might have multiple isolate intermediaries performing separate tasks. For example, it might be a facilitator that connected the migrant to an employer, but a completely unrelated document broker that helped the migrant get a passport. Other times, intermediaries worked in densely connected clusters within an ego-net. This was a common feature of migrations that used smuggler pathways via 'the jungle way' to get from the border to farther destinations like Bangkok, or recruiter coordinated pathways that relied on 'chains' of Myanmar and Thai agents. Figure 23 presents examples of different ways that social and intermediary actors were involved in different migration stages, sometimes linked and sometimes not. This figure was informed by examples described in the qualitative network narratives and validated in the ego-net visuals. See Appendix 6.3 for more qualitative insights on these linked or unlinked actors' involvement in different pathways

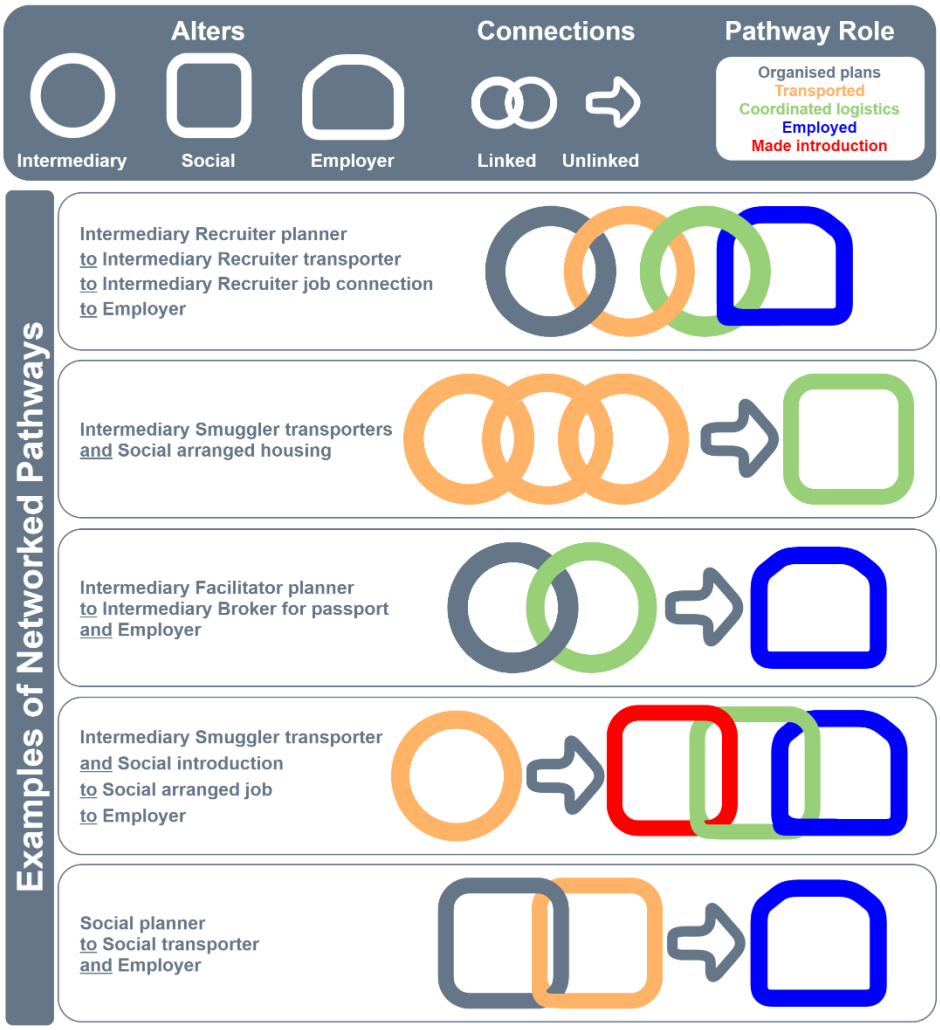


Figure 23. Networked pathways – alters, connections, and roles

Additionally, some alters did not help in direct ways but instead acted as 'bridges' between the migrant and other alters. For example, one migrant explained that their grandmother helped many migrants by connecting them with a Burmese speaking taxi driver on the Thai-side of the border in the Mae Sot area:

> "I rode [the motorbike] from the bridge to the factory . . . I did not understand anything at that time . . . So [the driver] helped me . . . he is Thai, and he is a friend to my grandma . . . My grandma used to

> send other migrants before me that way . . . So, my grandma has his phone number . . . He can speak Burmese too." (PID 610)

In another case, a social 'helper' in Thailand bridged an introduction between a migrant and contacts at a jobsite:

> "One of [my close friend's] nephews worked there before, and I got the job through that connection." (PID 216)

For most ego-nets (79%), the most central actor (i.e., the node with the highest 'betweenness' score[20]) was a family member and about half of the time (48%) the most central actor was also the person that invited the migrant to Thailand. This indicates the primary role these 'initiators' have in determining the migrant's connections to intermediaries and employers at destination, while being closely connected to the migrants existing social network at home.

For example, Ego 216 had a close friend that was very familiar with migration between Myanmar and Thailand (Figure 24):

> "I did the passport by myself . . . I travelled to Kawthaung the next day . . . [My friend] came and picked me up when I arrived . . .. He arranged the journey from Ranong to here . . .. He influenced my thoughts about migration . . . he gave me information and advice for my migration . . ..he told me about the do's and don'ts during the journey and how to talk if I met the police on the way to here and to always have my passport in hand . . .like that . . .he helped me arrange everything . . .his sister arranged the job for me . . .I migrated here with his nephew." (PID 216)

[20] The betweenness score reflects how frequently a node is on the 'shortest path' between two other nodes. For example, if node A and C do not know each other but they both known node B then node B's betweenness score increases because node B links these two actors. In an ego-net we look at the betweenness score for all the Alter-Alter links, *excluding* the ego and ego-alter links from these calculations.

In many cases, the centrality of an actor in a migration network reflected the direct role they played in influencing or even deciding a migrant's pathway choices.

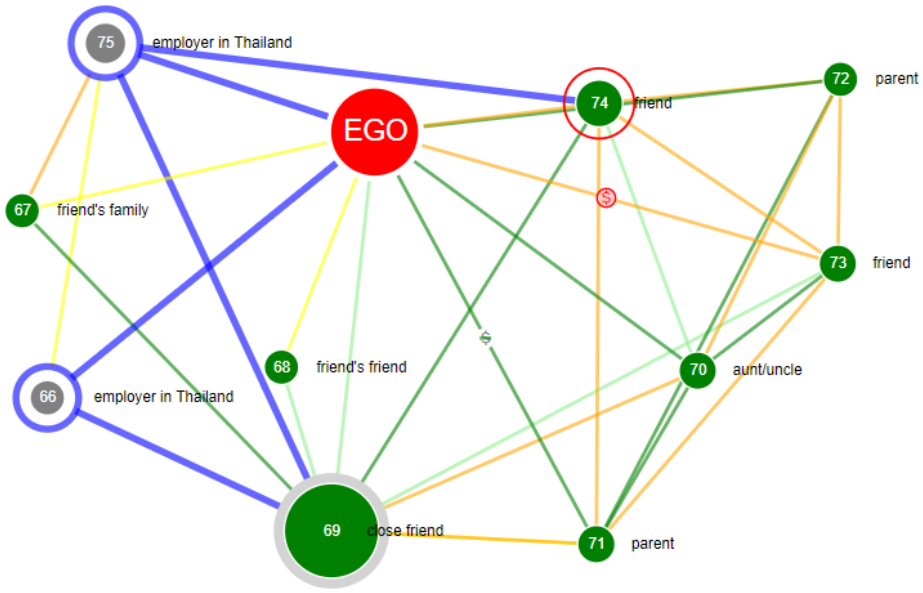


Figure 24. Ego-net example – central actor connecting home and destination

No two networks were the same, but there were often similarities in network composition based on the migration pathways. Figure 25 depicts the network visuals for four types of pathways (family, informal, solo, and regular):

Family pathways were the most common pathway respondents described and these were migrations that were almost entirely coordinated by or with family members. These networks were usually densely connected because they were primarily family members who all knew each other, and an employer that they all worked for or knew. Their network did not evolve dynamically apart from the addition of an employer at destination. The presence of intermediaries was less frequent, and if present, intermediaries

were more likely to be isolated actors performing a singular service but not planning or coordinating the overall pathway (Figure 25 - PID 501 and 602).

Informal pathways included intermediaries outside of the regulated recruitment process (i.e., the Myanmar-Thailand MOU process). These pathways had the greatest range of possible network compositions because of the range of actors and patterns of linking as described in the previous sections. Figure 25 gives two examples, Ego 221's network included facilitators that linked the migrant to a densely connected smuggler network, and Ego 606, whose network included two intermediaries involved at completely different stages and geographies of the migration. The informal pathways were far more dynamic than family pathways and usually included many more decision points and intermediary transitions.

Solo pathways were far less common than informal or family pathways and were the cases where a migrant decided and planned their migration with little input from others (Figure 25 - PID 207 and 623). These networks were often smaller with few or no links between destination and origin because they were not relying on family members or intermediaries to coordinate migration, usually just to finance or 'bless' the plans. Migrants using solo pathways might have a contact at destination, such as a friend or old neighbour, who might give them advice or make an introduction once they arrived, but these social contacts were not as involved as the family or intermediaries described in the previous two pathways.

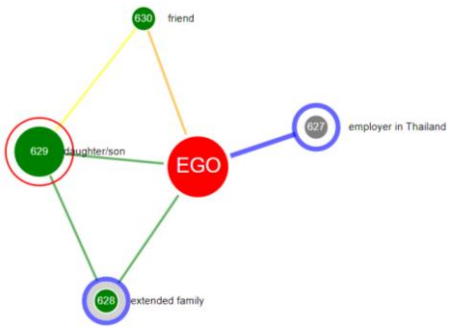
Lastly, **regular pathways** (or 'MOU pathways' in this context) were rarer in this sample, which reflects the trend that only ~10% of Myanmar migrants enter Thailand through regular channels (82). These were migrations that used licensed recruiters to arrange their work and travel to Thailand as part of the formal MOU process between Myanmar and Thailand. The agency hubs were in Yangon, to which migrants sometimes travelled independently. But, more often, there were facilitators that could connect rural migrants to

recruiters or recruiters that would travel to specific regions to recruit workers (Figure 25 - PID 514 and 418).

Actors were the defining feature of pathways because these different actors often had direct roles in determining migrants' plans – their destination, specific employer, documents they would take, fees they would pay, and borders they would cross. For example, migrants on family pathways would choose the destination and employer where their family member was, unless there was no vacancy and then they would find employment after arriving. Informal intermediaries varied, but if there was a link to a document broker in Myanmar then a migrant would attempt to get a passport before departing, which meant they would enter Thailand legally, even if without a work permit. A regular pathway usually had the 'package deal' of having the plan be pre-determined by the relevant agency. Solo pathways were often the least planned but usually individuals were migrating to the destinations closest to the border, because getting to those locations were the least likely to require documents or smugglers.

The network structures and corresponding narratives provided the whole picture of migration pathways, which included the way information, finances, decisions, invitations, offers, plans, and influence moved across network links to shape migration pathways. See Appendix 6.4 for additional exploratory analysis of network compositions and dynamics.

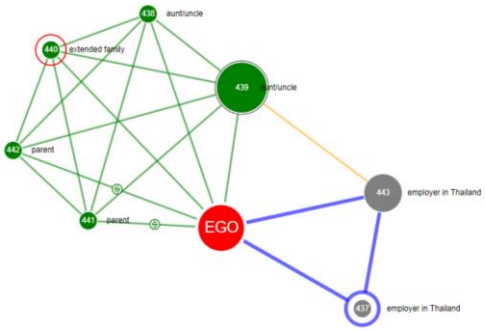
Family Pathway



Size: 7, Density: 0.86 (High)

Cousin coordinated her whole migration and hired her in Mae Sot. She later found other employment.

(PID 602)

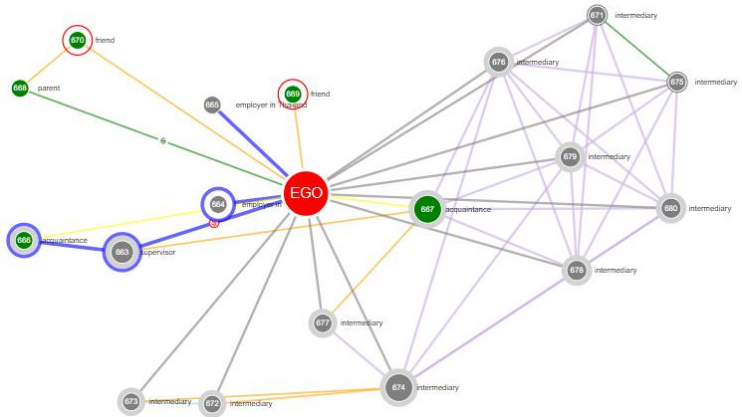


Size: 7, Density: 0.57 (Med-High)

Aunt and Uncle invited her and introduced her to a fellow migrant that connected her to employment

(PID 501)

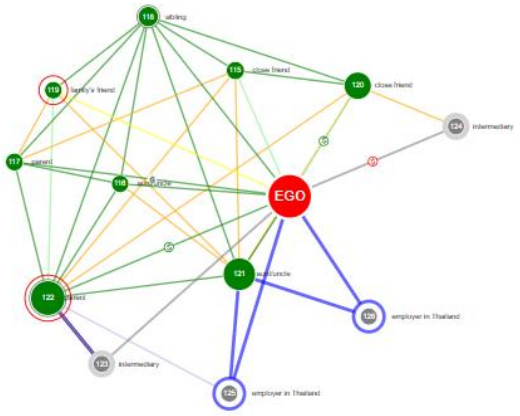
Informal Pathway



Size: 18 Density: 0.20 (Low)

Facilitators with loose links to a dense smuggler network.

(PID 606)

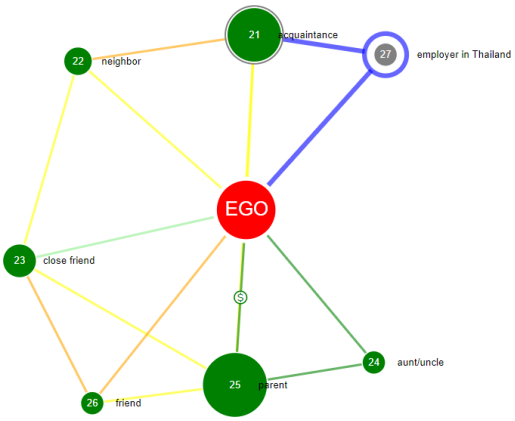


Size: 12 Density: 0.42 (Med)

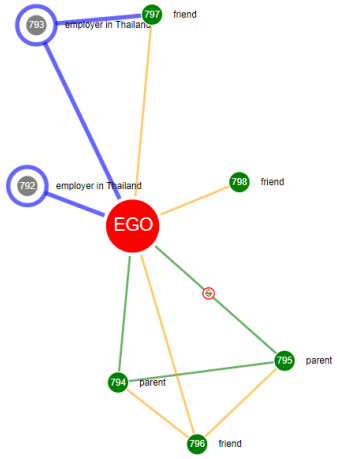
Informal broker that arranged passport in Myanmar and transit to Thailand, unrelated to a Thai document broker that arranged a work permit at destination.

(PID 221)

Solo Pathway

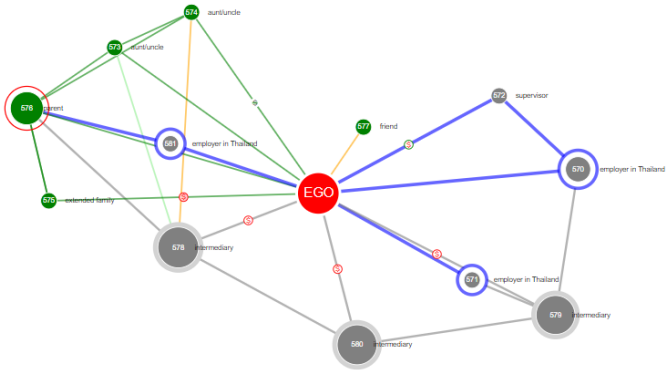


Size: 7, Density: 0.57 (Med-High)
ego asked contacts he had for advice and family for a loan for his migration plans.
(PID 207)

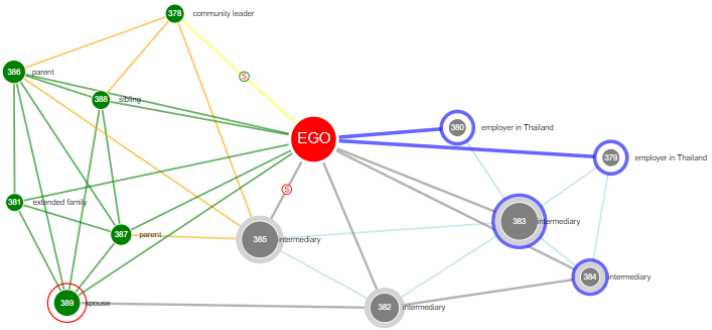


Size: 7, Density: 19 (Low)
ego decided to migrate on her own to Mae Sot using a border pass.
(PID 623)

Regular Pathway



Size: 12, Density: 0.21 (Low)
Village facilitator coordinated passport process and linked to MOU recruiters with multiple Thai employer contacts.
(PID 514)



Size: 12, Density: 0.35 (Low)
'MOU agent' came to village to recruit workers and then linked to Yangon agency.
(PID 418)

Figure 25. Networked pathway comparisons

3. Networks & Pathways

This final section describes three themes related to some of the mediated pathways discussed in the previous section: 1) pathway dependencies; 2) the diffusion of responsibility; and 3) different pathway choices for future migrations.

Pathway dependencies

Respondents described migration trajectories that ranged from minimally to completely planned. Often these plans were the result of decisions migrants made in the context of interactions with other actors. Migrants' options were determined by their social networks and local interactions, but the decision of which pathway to choose was guided by a combination of preferences and conditions. For example, some migrants said they used 'informal pathways' because they could not afford the costs of documents and recruitment fees for the 'regular pathway'. In other cases, migrants living near the Thai border explained that they did not need to use a mediated pathway (informal or regular) since migration was easily achieved without help (i.e., 'solo pathway'):

> "I do not know about recruiters. I just stay at Kawthaung (border-crossing town in southern Myanmar), so I do not need to come here with an agent." (PID 207)

The choice of a pathway then determined to some extent the degree of planning and details of those plans, such as destination, pre-migration documentation, transit route, border crossing, or employment plans. These plans were often pathway- *and* actor-specific, based on the steps of migration involved (refer back to Results Section 1). For example, all facilitators might offer typical sets of migration plans (destination, employer, link to a smuggler) compared to smugglers who will offer a different set of plans (border crossing, destination), while an *individual* facilitator will offer a specific set of named plans within this typical combination. This means that

the interactions, options, and preferences at early stages of migration often created pathway dependencies at future stages. For example, if a migrant accepts a smuggler's offer it is unlikely that they will even consider acquiring a passport before migrating because it is not needed for that pathway. Alternatively, if a migrant accepts a document broker's help to acquire a passport, they will not use a smuggler as well since travel will occur via the official immigration checkpoints and major transport routes. Ultimately, the migration network and associated plans determines the course of future decisions and actions.

There were several examples of how the presence of social contacts, primarily family, in Thailand determined migration plans. For example, if a migrant had family members that could arrange the migration, then they would not rely on intermediaries, especially when there were financial restrictions. Ego 508 explained his decision to cross the border at Mae Sot illegally with help from his father:

> "My father has been here so I followed with him, and I do not need to use [intermediaries] because we can easily travel to the border city Mae Sot . . . Some simply and illegally crossed into Thailand while others who can afford to make their documents and migrate to the big cities like Bangkok." (PID 508)

If a migrant's migration was suggested by a social contact in Thailand who invited them to migrate for a specific job, then the migrant would be less inclined to go the 'regular pathway' because they did not need recruitment services as that recruitment would likely result in a different employer plan. Similarly, if a migrant was able to secure a document to *enter* Thailand legally (e.g., a passport with a visitor's visa), then they would cross the border legally to get the required stamp on this document. However, individuals who had an option to *enter* legally, may choose to engage in undocumented work if they entered on a visitor's visa or border pass and did not have a

work permit. One migrant explained this as a pseudo-regular alternative to the MOU process:

> "[Migrants] do not need recruiters if they have documents. They can enter Thailand with this passport. If they do not know how to come, I can come and pick them up. I can go and pick them up near Thai borderline because I am their friend." (PID 204)

In the cases where migrants used licensed recruiters, they then had limited choice over their destination and sector of work and could not easily change employers after they arrived. These 'regular pathways' included legal entry and documented work, but as Ego 608 explains, this pathway then limits certain options after arrival:

> "You can go to Thailand with a passport for a fixed term and the job is ready for you, but you do not have the right to change your job, but our system [migrating through social connections] allows us to change the job." (PID 608)

Migrants had various explanations for choosing specific actors to be involved (e.g., destination or work preferences, low fees, only trusting family invitations) and their plans then naturally followed these choices, which then often influenced their future access to jobs, documents, protections or freedom at destination.

Diffusion of Responsibility

When migrants had multiple decision-makers or several intermediaries in their migration network, it was not always clear whose direct responsibility it was if or when something went wrong. Respondents were hesitant to blame specific actors. For example, in a few cases, individuals that used the regular MOU pathway faced a range of problems at their first job site (e.g., different employer than promised, unpaid wages, employers refusing to let them leave). In these cases, migrants more often blamed the intermediaries at the end of the chain in Mahachai than individuals that were initially involved in connecting them to the agency (i.e., local facilitators at home) or

that arranged their contracts in Yangon (i.e., Myanmar side recruiters). For example, Ego 418 describes how a male broker persuaded him to migrate and gathered migrants in his village to transport them to Yangon and introduce them to the recruiters. In Yangon, it was a female broker and recruiter that then arranged their work placement. Ego 418 explained the reputation of the male broker and then explained who was to blame for problems in his migration to Thailand:

> "Fellow migrants in my village recommended [the male broker that gathered us] . . . he has a good reputation in our village . . . I also used him for my migration to Malaysia . . .and it was smooth and sound . . ..So, I decided to use him again to come [to Thailand], but it was not smooth. . . . we had to pay him a lot of money . . . but it was the Thai female broker and recruiter that cheated us, and they intentionally caused us problems." (PID 418)

In another case, a migrant was trafficked into fishing work and when asked a similar question about culpability of intermediaries, he blamed the two facilitators that recruited him in the tea shop in Myawaddy and the woman that hosted him in Myawaddy, but in this case he did not ascribe blame to the smugglers that transported him and dropped him off at the boat on which he was forced to work without pay for 6-months. Further, when asked who gave him the most valuable support in his migration, he said it was his supervisor on the boat, who was his first point of contact when the smugglers dropped him off. This migrant did not perceive that either the smuggler or the supervisor were responsible for his extended period of debt bondage:

> "Yes, those two facilitators and that lady from that house . . ..Because of them, my life was miserable . . ..[The smugglers] treated me well during the migration . . . I met the facilitators at the tea shop, [they] searched for the migrants and then they sent them to the lady from the house . . . The lady from the house phoned to those four smugglers to come and pick us up . . . The guides brought us to Bangkok and the boss paid them. . . . [My supervisor] gave me the

> most help because he arranged everything for me. . . . When I left his boat, he gave me my remaining salary. . . . I got like 2,000 Baht (~$65 USD)." (PID 606)

This diffusion of responsibility and the different targets of blame occurred in both regular and informal pathways. In one MOU migration case where a group of migrants did not get the jobs or wages that they were promised, one migrant explained that it was not the village facilitator's fault, but the recruiters' fault. She said:

> "The facilitator will arrange everything for us, she will connect us with the recruiters . . . I like the facilitator, but not the recruiters." (PID 420)

Migrants seemed reticent to ascribe blame to anyone that did not directly cheat or harm them, even if individuals had given them unreliable information or were seemingly complicit in their unfair recruitment or exploitation.

Network dynamics across multiple migrations

For most of the sample (70%), this was their first migration and many migrants explained they might make decisions and plan differently for future migrations. In some cases, migrants said they would rely on fewer people next time or use different pathways. For example, many migrants said they would not ask for help again since they were now more knowledgeable on how migration worked:

> "I know everything about here so I will not go and ask advice from anyone [next time]." (PID 206)

> "I will migrate by my own decisions because I have already been here, and I know how to travel." (PID 603)

In other cases, such as Ego 605, migrants felt they had expended all the support they could ask for:

> “I have decided that I will not go and ask help from others again. I already asked for a lot of help from others so I should not ask anymore. I will try hard by myself.” (PID 605)

Migrants also talked about using different plans to acquire documentation, trying new destinations, or choosing different pathways for future migrations:

> “I think I will migrate again illegally, and I will make the passport later.” (PID 512)
>
> “I am not OK here, so I will go back to the village, and I will plan to migrate to other countries like Macao or Korea.” (PID 803)
>
> “I will come with the legal way next time.” (PID 222)

Migrants’ ideas about future migration suggest that more experienced migrant workers will adapt strategies and networks to undertake alternative migration plans.

Discussion

Around the world, millions of migrants put their fate into the hands of individuals that they hope will help them migrate to jobs and better incomes. To date, in many migration corridors, there has been little research on these labour migration processes and the complex networks of actors that facilitate labour migration.

Safe migration rhetoric often assumes that migrants make one binary decision after the other (e.g., travel with person A versus B, go by route X versus Y) and that many of these decisions are made at a single point in time before the migrant leaves home. Further, it is often presumed that it is possible for prospective migrants to access accurate information about their migration options before they depart. In fact, international dialogue on 'fair recruitment' reinforces these simplistic dichotomies because they rely on a narrow understanding of labour migration intermediaries. That is, international and non-governmental organisations working to address risks related to migration frequently try to make clear distinctions about actions and actors, which are, in fact, much more ambiguous. For example, migrants seldom ask themselves: *Will I migrate legally or illegally? Will I use the licensed agent or the off-book broker?* More often they are asking questions like: *What people do I know to help me get to Thailand quickly like that other person did and find a job that is not outdoors?* Or: *Which of the intermediaries are promising the highest wages and is it ok to go to that destination without a document?* Our current frameworks and corresponding programming for safe migration and fair recruitment do not adequately reflect migrants' lived experiences, preferences, intermediary choices, thresholds for uncertainty, or decision-making processes.

Implications for intermediary terminology

The results of this research suggest that the various individuals involved in labour migration do not readily conform to clear cut labels and there are conceptual flaws to how labour intermediaries and recruitment are currently defined. In migration dialogues, it is sometimes implied that an 'intermediary' or even 'broker' always mediates entry into work, but in line with Katharine Jones's working definition of intermediaries (61), intermediaries assume a wide range of roles relevant to migration and employment coordination across all stages of migration, even mediating introductions to other intermediary actors for subsequent migration steps. Jones's study, like this study, also highlights the complex nature of migration and recruitment networks that cannot be easily categorised into simple rubrics (e.g., social networks, smuggling networks, trafficking networks). Migration and recruitment networks are, by their very nature, diverse, dynamic and internally influenced based on who is involved and when. The results indicate that these varied actors are not confined to one type of migration pathway (e.g., facilitators working across legal and illegal pathways) and thus they interact within multiple local systems in one larger complex system. Other research findings in Myanmar-Thailand have highlighted similar findings on how informal brokerage is often embedded in the state-managed migration pathways (247). A recent global review of intermediary practices concluded that migration is made possible through networked entities irrespective of the heterogenous motivations and functions of the actors within these entities (61). The review results further highlight the nuances of intermediary-migrant relationships and exchanges that do not conform to some of the mainstream assumptions. A recent collection of global studies on human smuggling has unpicked the predator-victim binary often used to describe these 'criminal' networks. The authors found that in many contexts, this binary is an ineffective portrayal of transit pathways that does not capture some of the adaptive and symbiotic

relationships between smugglers and migrant communities (248). To ensure that future understanding of labour intermediation represents migrants' reality, it is necessary to gain more in-depth and contextually relevant perspectives of who are the intermediaries and what they do from the perspective of migrants in different locations that use different pathways.

Our findings indicate that intermediary roles might include, for example: actors that help migrants plan their migration; actors that bridge migrants to intermediaries; actors that are paid by entities to facilitate legal labour migration; actors that transport; actors that connect migrants to work outside of legal channels; actors that help arrange documentation outside of the legal channels; and actors that offer coordination support at any stage without charging fees (usually social contacts). These categories capture a broader range of people involved in an individual's migration beyond the scope of 'recruitment'. Moreover, these wider set of categories help make more precise distinctions beyond licensed versus unlicensed. Further understanding then requires additional probing on *how* these groups work and differentiations based on intermediaries' locale, relationship to the migrant, and specialisation of services they offer. For example, our results found that facilitators and brokers can offer very similar services (planning, transport), *but* facilitators were more often involved across multiple migration stages, whereas brokers commonly assisted with discrete steps. Additionally, brokers comprised one category, but brokers that were social contacts were more often involved in linking migrants to work, whereas brokers that were only functioning as intermediaries were more often involved in the migrant's transit plans and transportation. Until we gain a more realistic representation of the heterogenous components of migration and intermediary networks, the use of terminology that is vague (brokers), narrow (recruiters), or dichotomous (legal or illegal; safe or unsafe) will continue to misguide our research questions and in turn confuse the theories of change embedded in safe migration policy and interventions.

Implications for migrants

The results have implications for the options Myanmar labour migrants have when they are making decisions under a range of uncertainties and often with multiple restrictions to their decision-making (e.g., cost, time, family influence, occupational skills). The findings show that there is no reliable pathway between Myanmar and Thailand that can guarantee safety *and* ensure migrants meet their goals for migrating. Even migrating through a supposed 'gold standard' legal migration pathway that integrates principles of fair recruitment, such as the Thailand-Myanmar MOU process, can result in large debts, unmet expectations, and exploitative working conditions, in addition to potentially long delays. In comparison, migrants that rely on social networks may have more accurate information and guarantee of a job at destination but will be without protections that come with having the legal rights to work. Our results demonstrate that migrants made multiple and multi-faceted decisions and generally had to rely on multiple actors from home to destination. Although migrants made efforts to make informed decisions (e.g., they observed other migrants' behaviours or sought out advice from knowledgeable sources), there seemed to be little they could do to predict outcomes when so many uncertainties surrounded intermediary use, pathway choices, and destination outcomes. Myanmar migrants' perspectives on "unlucky encounters with bad brokers" or "wishing for good brokers" echo findings from other labour migration research which noted that migrants view 'successful migration' as a matter of luck (55). Theoretical work on migration decision-making under uncertainty poses that uncertainty specifically about conditions at destination is the type of uncertainty that leads to 'try your luck' decision-making, as opposed to uncertainty about home conditions which may lead to 'wait and see' decision-making (116). Our findings on migrants' motivations and decision-making indicate that many migrants feel confident their home situation will not change and thus their uncertainty is more often

about what they will face in transit or at their destination. This leaves migrants in a relatively challenging position in terms of identifying a reliable intermediary or a 'safe migration' pathway. These study results indicate that migrants cannot expect guarantees, but that social contacts or known intermediaries often offer the most assurance for better or at least more predictable destination and work outcomes—but at the cost of legal status and any protection that might confer. Thus, for many migrants the most reasonable decision might include an informed trade-off of risks. That is, migrants might choose to migrate through irregular social channels that limit the upcoming uncertainty of job outcomes and accept the known risks of deportation or fines in the future. The 'safest bet' for migrants might be taking the lowest cost and most direct route to a job, which in many contexts will not be the legal migration pathway.

Implications for interventions

While many of the results suggest that migrants' can perceive that their migration trajectory may come down to luck and 'good' or 'bad' intermediaries, findings also indicate that there are certain decision-making moments and network interactions that can influence how Myanmar migrants plan or implement their migration, possibly restricting or enabling future pathway choices. Migrants had specific advice and support at the early stages of migration that were not always consistent or available at later stages. Migrants also made decisions to enter Thailand or find work based on social connections or resources immediately available and these were not always rational decisions during which migrants 'optimised' all possible outcomes. These findings fit well within many migration frameworks that highlight that migration happens in stages (or 'steps') at which different interactions, decisions, risks or opportunities might be present (5, 114). Our findings suggest that 'safe migration' interventions, especially recruitment services, need to position themselves across migration stages versus solely pre-departure. Interventions cannot assume that migrants will choose the

bona fide ‘safe and legal’ migration pathway at the outset—as for many, this will not seem like the rational choice. This assumption about the centrality of pre-departure decision-making moments unintentionally punishes migrants that pursued avenues that seemed most logical, convenient or even safe—not necessarily because they did not have access or incentive to migrate initially using legal pathways. In other words, we need to create more pathway options so that when the safe migration train leaves the station those that did not board at the first station have feasible options to board later regardless of their previous or current legal status.

Moreover, and perhaps conversely, our results also indicate that in the Myanmar-Thailand corridor, legal migration is not always a guarantee of safety or success and that migrants seem to prefer informal intermediaries and irregular pathways especially when they are recommended by family or friends. In this study, many migrants explained that informally facilitated migration, or what one migrant called ‘our system’, often provided migrants with better information and work connections and was less costly and time consuming. Recent secondary analysis of data from an ILO-IOM study on migration from other ASEAN states, primarily Myanmar, to Thailand found that ‘regular’ migrants were most likely to report working conditions that did not meet legal standards and contract substitution. This analysis also found that for many migration outcome indicators (average working hours/days and monthly wages), regular and irregular migrants had similar experiences, and in fact, regular migrants were more likely to have experienced deception and broken written or verbal agreements and more likely to return home due to exploitation or lost job than irregular migrants (249). Other research in this corridor indicates that a small minority of Myanmar migrants use the only legal channel in the Myanmar-Thailand corridor (i.e. MOU migration) because these processes are too complicated, costly and slow (63, 83, 91). These are serious obstacles to the ‘fair recruitment’ model, which is contingent on legal migration. Recent research

applying Bayesian Network Analysis to primary data from Nepalese labour migrants indicated that labour intermediaries were determinative in the outcomes of women who migrated for domestic work to the Gulf States. While our research among Myanmar migrants confirms the importance of the role of labour intermediaries, it also strongly indicates that labour intermediaries are comprised of a very diverse set of individuals who fulfil a wide range of roles or single tasks. This diversity has substantial implications for individual migrants, and therefore offers lessons for the programs and policies that are trying to regulate labour intermediation by thinking of it as a singular process involving a limited and predictable number of actors or agents. A reductionist, 'one-size fits all' fair recruitment model discourages what should be a broader exploration of risk and safety in labour recruitment channels. As a result, interventions often fail to address how different migrants navigate the many and varied forms of unplanned or informally organised migration pathways. For the time being, until migration policies and regulations can be improved to serve actual labour migration trends, a true global model of fair recruitment needs to include interventions in irregular migration pathways as well as legal ones. Current tripartite safer migration initiatives are often bounded by national and international laws to govern orderly and regular migration, which are often restricted in the ways they can reflect migrants' reality and prioritise their safety, wellbeing, and logical preferences. The current fair recruitment model is fair recruitment for *legal migration* and should be branded as such until it can navigate how to offer protections in irregular pathways or acknowledge this is an insurmountable challenge to current stakeholders' approach to fair recruitment.

Implications for policy

In the same vein of expanding fair recruitment to irregular pathways, future interventions will have to figure out how to guarantee fair recruitment within legal pathways. Our findings show that it was not uncommon for

migrants to trust the formality of the MOU system or recruiters, sometimes against their better judgement and at the expense of their limited resources. If the MOU system cannot guarantee safety and fair outcomes, and migrants are unable to determine which intermediaries or agencies are practicing fair recruitment within the MOU system, then these systems cannot really continue to be promoted as 'safe'. Currently, many of the policies and corresponding interventions under the umbrella of fair recruitment have not yet been proven to be effective in protecting migrant workers, and thus programmes must proceed cautiously with how these initiatives are branded for migrants. Findings show that licensed agents and agencies, even those functioning in well-known hubs like Myawaddy border areas of Myanmar or facilitating contract signing in local government buildings such as town halls, are charging migrants exorbitant fees and not delivering on promised jobs. Weak enforcement of fair recruitment in the MOU system is in fact perhaps the most unethical form of recruitment as it deceives migrants that feel they are abiding by the rules and adhering to the recommended procedures.

Implications for research design

Taking an evidence-based approach to addressing complex social problems, such as labour migration mediation, requires research methods that can capture and explain complex causality. The results from this research indicate that an essential first step is to collect dynamic relational data that provide insights on *process, mechanisms* and outcomes over time, geographies, and changing social contexts—and which take account of migrants' reality. The findings on intermediaries highlight that the way we ask about individuals' involvement in the migration process is important. Oversimplified questions will reinforce some of the false dichotomies and vague understandings about intermediaries. Mixed methods social network analysis offers a more accurate picture of the people and interactions involved in labour migration and addresses both the who and how of

migration mediation. This method of collecting relational data can provide insights about the larger system of migration and explore the complex causality found in migration networks and pathways. One promising next step for this research, and similar studies, is to use causal inference and complex systems methods, such as Bayesian Networks and Agent Based Modelling, to explore the probabilities and rules that show the actor interactions, network composition, and pathway choices to labour migration outcomes. The structural and thematic relational data collected and analysed using MMSNA can now be used to inform model rules on the micro-interactions in the system to observe if the macro level patterns reflect what is happening in the real world. These methods will help us test whether our understanding or assumptions about *how* individuals in the system act or whether the rules of the system are in fact a reliable basis to inform safer migration interventions and policy. These methods will also help us develop and test interventions *in silico* that would normally be too costly or ethically impossible to test in the real world.

Limitations

To achieve diversity of pathways and outcomes and considering the hard-to-reach nature of the study population, we adopted a purposive sampling strategy. The sample size (n~80) was calculated to achieve large enough subgroups for the statistical descriptive analysis, and at the same time allow for in-depth qualitative case analysis. Although the study sample is not representative of the whole population, quotas associated with gender, regular vs irregular pathways, work sector and destination were achieved. This paper presented an overview of findings. Future analysis will explore how aspects linked to gender, age/generation, migration history, or ethnic background may interact with migration pathways, experiences and outcomes. Because the sampling strategy did not purposively seek out to include the more severe labour exploitation cases, it is impossible to say if there are trends in pathways into a narrow set of outcomes that are not

addressed by this research. Furthermore, the sample only included migrants, which limits what conclusions can be made about the behaviours, motives, and decisions of the other network actors (social contacts, intermediaries, employers).

However, because the sample included a wide range of demographics (age, gender, origin areas) with a variety of migration experiences (intermediaries, routes, destinations, employment) the findings do contribute valuable insights into a broad group of migrants' experiences in this corridor.

Conclusion

Legal migration is not always safe. Illegal or 'irregular' migration is not always risky. Brokers are not exclusively 'bad' and formal recruitment is not always what it says on paper. Migration pathways and outcomes are nonlinear, meaning that more formality does not always equate to greater safety. It is not uncommon to hear acknowledgement of the 'complexity' of labour migration and the problem of labour exploitation, but, to date, that has been much too limited accounting for complexity in terminology, interventions, policies, or research. The reality of migrants' experiences means that the only potential road to helping them to safer migration and fair work conditions will require both complex systems thinking and interventions that can operate in the complex world where migrants travel and work.

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Thesis Title	Mediated labour migration in the Myanmar-Thailand corridor and precarious outcomes: a mixed methods social network analysis and agent-based model		
Primary Supervisor	Cathy Zimmerman		

SECTION B – Paper already published

Where was the work published?			
When was the work published?			
If the work was published prior to registration for your research degree, give a brief rationale for its inclusion			
Have you retained the copyright for the work?*		Was the work subject to academic peer review?	

SECTION C – Prepared for publication, but not yet published

Where is the work intended to be published?	Journal of Artificial Societies and Social Simulations
Please list the paper's authors in the intended authorship order:	Alys McAlpine, Luke Demarest, Ligia Kiss, Cathy Zimmerman, Zaid Chalabi
Stage of publication	**Submitted**

SECTION D – Multi-authored work

For multi-authored work, give full details of your role in the research included in the paper and in the preparation of the paper.	I led the study design, data collection, model design and analysis, and wrote the first draft of this paper.

SECTION E

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Date	27-06-2021

Supervisor Signature	[redacted]
Date	27-06-2021

4.4 ABM findings

4.4.1 Preamble to Paper 4

The final paper of this thesis presents an empirically-based ABM of low wage labour migration networks, pathways, and outcomes in the Myanmar-Thailand corridor. Using the MMSNA dataset and findings, this ABM is informed by a rich set of cases that shed light on the micro-behaviours of migrants, intermediaries, and employers that form egocentric migration networks engaging in migration pathways. Complex systems thinker, David Byrne, notes a resonance between the ways in which 'cases' and 'complex systems' are defined and the use of in-depth and comparative methods, often qualitative, to holistically explore configurations of characteristics (250). Citing Abbott, Byrne goes onto argue that approaching individual realities as "heterogenous, fuzzy, sometimes alike, and sometimes critically distinct from one another" is a starting place for understanding micro-level complexities that shape meso-level networks (250). The methods of this paper have been guided by the learning and insights of the systematic review presented in Paper 1. The model design was informed by the empirical research presented in Paper 3, which was conceived with ABM in mind as evidence in Paper 2. It is rare in ABM research that the modelling team has first-hand deep knowledge of the data collection and fieldwork context as most agent-based modellers use data sources they were not directly involved in collecting. Like much of this thesis, this ABM presents both empirical and methodological contributions, in part, to respond to the methodological gaps in current empirical ABM methods and to suggest new approaches that are needed to achieve such empirical aims.

This final paper has been written in preparation to submit to the *Journal of Artificial Societies and Social Simulation*. Some of the content of the paper will be moved to 'supplementary material' to meet the JASSS word-count maximum but has been left as an extended version in the thesis submission.

4.4.2 Paper 4

Migration networks and pathways into precarity in the Myanmar-Thailand corridor: an agent-based model

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Keywords: migration, labour exploitation, empirical data, agent-based model, social network analysis

Acknowledgements: AM led the study design, data collection, ABM design, ABM analysis and write up; LD programmed the model and data visualisations; ZC reviewed the translation of the conceptual model and empirical analysis into model-based rules; LK and CZ reviewed the model assumptions and rules for domain accuracy. (See Appendix 7 – Part 1 for more detail on team members roles in this interdisciplinary project)

Abstract

Low wage migrants often experience precarious or exploitative work that has significant impact on their health and wellbeing. Promoting safe migration and decent work is a pressing policy question. The Myanmar-Thailand Migration Planning and Intermediary Networks Agent-Based Model (MyTh MaP-IN ABM) simulates migration decision-making, planning, and implementation processes embedded within social and intermediary networks. The model aims to describe how these migration networks shape migrants' pathways to destination, which in turn determine their experience of 'hyper-precarity'. The analysis compares three scenarios, two of which are informed by current interventions addressing unfair labour recruitment. The model rules were calibrated using primary mixed-methods social network analysis, which was conducted as part of the overall study design. The model was evaluated using multiple stages of verification during design and implementation as well as a saturation test for the model rules and pattern validation of system level patterns. The outputs included the dynamics of migrants' decisions and the emergence of different levels of precarity across different migration pathways and social network compositions. The observations of these simulations indicate that migrants' experiences of *hyper*-precarity (individual and situational experiences of precariousness at destination) in the Myanmar-Thailand corridor follow similar trends that cut across all migration pathways but reach the highest levels of precarity in the regular or documented migration pathway. Furthermore, over time, most migrants experience a decrease to their level of precarity through a series of actions taken after arrival at their workplace destination, but, alternatively, they might experience increased precarity in certain cases. This paper contributes a novel mixed-methods, empirically-based ABM that contributes methodological learning to the field of computational social science and programmatic insights to the mounting programmatic debates on human trafficking prevention and 'safe migration'.

Unsafe migration – what are the mechanisms?

A pressing policy question related to migration is how to promote safe migration and migrants' entry into decent work to avoid exploitation or human trafficking. Most international migrants, regardless of their motivation to migrate (e.g., unemployment, conflict, curiosity), engage in employment at their destination (15). Many migrant workers resort to low-wage '3D work' (dirty, dangerous, and difficult), in which they experience disproportionate occupational harm and employment abuses compared to their native counterparts (6, 8, 47). In some cases, these abuses amount to severe forms of labour exploitation or human trafficking, which are often grouped under the term 'modern slavery' (7). Global estimates indicate that a quarter of the 25 million victims of forced labour are international migrants (4). Evidence also illustrates the life-altering impact that occupational injuries and exploitation have on migrants' health and wellbeing (2, 8, 58).

The United Nations (UN) Sustainable Development Goals (SDG) outline targets to achieve safe migration[21] and decent work for all[22] (9). However, essential evidence to inform prevention is still relatively inconclusive on the causal mechanisms that link migration and severe forms of labour exploitation (14, 251). This evidence gap is due, in part, to the limited application of research questions and methods that address the phenomenon of migrant labour exploitation as a complex system and that engage with concepts of complex causality and dynamic feedback in designing social interventions to reduce migrant labour exploitation (252). Moore and colleagues explain that "[social interventions] are complex

[21] UN SDG Target 10.7: Facilitate orderly, safe, regular and responsible migration and mobility of people, including through the implementation of planned and well managed migration policies.

[22] UN SDG Target 8.8: Protect labour rights and promote safe and secure working environments for all workers, including migrant workers, in particular women migrants, and those in precarious employment.

primarily due to the social systems within which these actions occur, the contextually contingent nature of impacts, and the agency of the groups and individuals whose behaviours they aim to influence." Moore draws on the work of Hawe and colleagues to add that social interventions are not "decontextualised components" of these systems but are more akin to "events" that aim to disrupt the dynamics of the system (13, 253). In this paper, we argue that current safe migration initiatives, which include 'fair recruitment' interventions, have not sufficiently engaged in complex systems thinking to understand the labour migration system's dynamics that these interventions aim to disrupt. There is an especially acute gap in understanding of how migration mediation (i.e., labour or migration brokerage) works, or does not work, in these systems (61).

There is not a universally agreed definition for 'fair recruitment' but the International Labour Organization (ILO) describes fair recruitment as "[labour] recruitment carried out within the law, in line with international labour standards, and with respect for human rights" (11). The ILO, UN, and other international stakeholders are directing significant investments into 'fair recruitment' initiatives in response to emerging evidence that links 'unfair recruitment' with labour exploitation (e.g., exorbitant fees, contract swapping) (69, 71). However, the implicit programmatic assumption being championed by these efforts is that *regular* (i.e., via official processes) migration coordinated by licensed recruiters is protective, and the alternatives – illegal migration, informal mediation – are 'risky'. Arguably, the evidence base justifying this theory is weak (14, 82, 249) and there has been minimal research that considers the current dynamics of migration mediation from a complex systems approach.

For example, our understanding of labour migration intermediaries (i.e., actors that "foster, facilitate or sustain human mobility" (61), such as 'recruiters' or 'brokers') is still too opaque to conclude which mediated (or

'unmediated') pathways are 'risky' or protective. Research has not explored the dynamics of pathway-specific risks over time and geographies or the role of social interactions and networks in determining migrants' preference for and use of different pathways. Evidence on the true diversity of intermediaries, their role in migration networks, and migrants' decision-making approaches to choosing mediated pathways is an essential starting place to critically explore the role of 'fair recruitment' interventions in disrupting patterns of human trafficking and modern slavery in the complex low-wage labour migration system.

Agent-based modelling for migration intervention research

Agent-based modelling (ABM) offers a promising way to explore the heterogeneity, interactions, dynamics, feedback, and emergent phenomena of real-world migration systems (134, 136, 254). This method can be used to simulate how migrants and other actors (family, intermediaries, employers) operate as autonomous agents that make migration decisions, enact plans, move, and make exchanges based on simple sets of rules. ABMs can be used for many different purposes (255, 256), including as 'in silico' laboratories to test counterfactual scenarios, such as safe migration or fair recruitment interventions (151, 257). While there have been extensive criticisms of what ABMs can promise in terms of prediction, social scientists using ABM argue that this methodology can help us to organise complex problems and systems into cognitively manageable descriptions of how the system works. Social scientist and modeller Corinna Elsenbroich argues that ABMs can provide useful "mechanism explanations" and that any claim that they only produce 'partial' explanation is really an accusation against all social science methodologies, not a unique shortcoming of ABMs (258). Social simulation methods offer unique benefits for safe migration interventions because not only do they provide insights on unanswered questions about *mechanisms* in safe migration approaches, but this method also circumvents many of the logistical and ethical constraints to using more conventional evaluation

approaches to test interventions with this hard-to-reach population (e.g., RCTs).

By using ABM, the essential characteristics of a highly complex migration system can be abstracted into simpler environments (i.e., low-definition origin and destination spaces) or typologies of actors without losing the complexity of the system process. Modern slavery has been described repeatedly as a complex, 'wicked' problem, which suggests that it is our methods not our conceptualisations that fail to harness complexity science and thinking. To date, ABM has been under-utilised in migration and modern slavery research. Moreover, when utilised, the models are rarely informed by empirical data to adequately represent an ABM's multiple levels and entities (254).

To our knowledge, this paper presents a first-of-its-kind ABM that simulates low-wage labour migration pathways embedded within social and intermediary networks to explore how these mediated pathways influence migration outcomes. This model allows a more thorough exploration of how the dynamics of the system work and a more transparent and critical assessment of programmatic assumptions.

First, this paper presents our methods, which include the model design and outputs, and how we conducted scenario analysis and model evaluation. Then we report the findings from the 'pre-simulation' model evaluation stage, which included conducting conceptual model validation and specification verification, before progressing to a completed simulation. Next, we present the scenario analysis, which is then followed by a second stage of model evaluation that included simulation verification, simulation validation, and sensitivity analysis, and a critique on the limitations of the model. The discussion of this paper reflects on both the empirical and methodological contributions of this work.

Methods

Model description

This section presents a shortened overview of the model ODD+2D documentation that can be found in Appendix 7. The ODD+2D[23] is an extended version of the original ODD protocol created to bring structure and consistency to the way ABM modellers document and share their models (137, 166, 259).

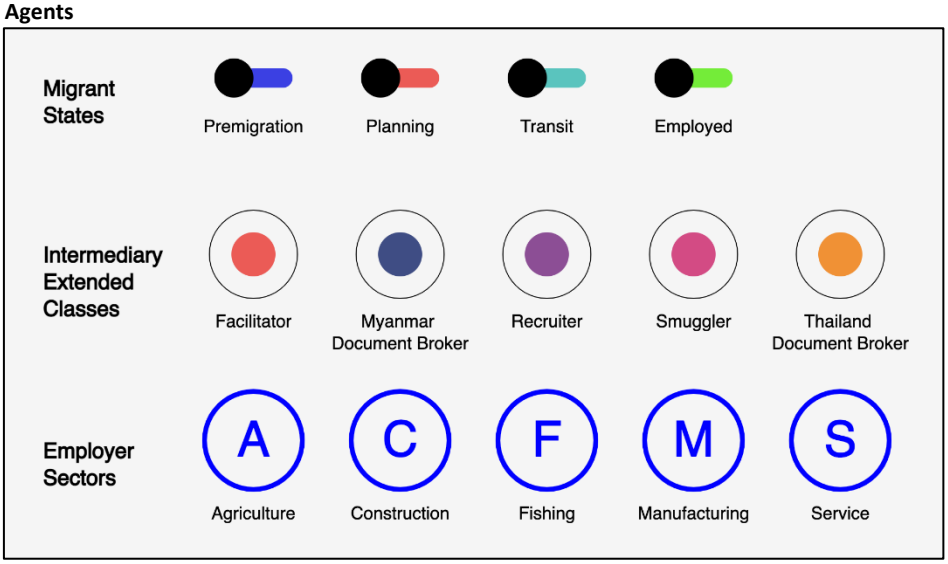
Purpose. The Myanmar-Thailand Migration Planning & Intermediary Networks (**MyTh MaP-IN**) ABM is an empirically-based, descriptive model (256) that preliminarily explores the impact of 'fair recruitment' theories of change (11). The model aims to contribute a new conceptual understanding of mediated migration pathways, dynamics, and outcomes, specifically in corridors with high rates of irregular migration like in the Myanmar-Thailand corridor. This model first describes the complex system that gives rise to high rates of irregular migration and then explores the relationship between migration pathways and precarity (defined in the next section 'Model outputs'). Ultimately, this model responds to the questions: *How do experiences of 'precarity' differ across migration pathways, time, and intervention scenarios?* And: *What emergent properties can we observe about the migration system's sociocentric network?*

Entities. The model consists of three agent classes, migrant, intermediary, and employer. Each has heterogenous properties, such as migrant *states*, intermediary *types*, and employer *sectors* (Figure 26-A). The abstract model environment represents Myanmar (*origin*) and Thailand (*destination*) divided by a border (black vertical line) and consisting of multiple sub-areas

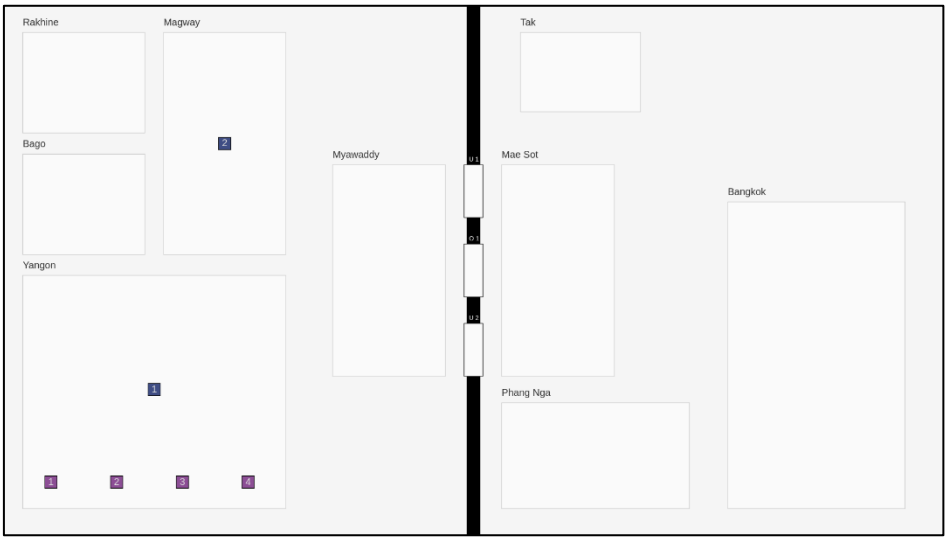
[23] The ODD+2D protocol (259) is the 2018 extension the original 2006 ODD protocol later updated in 2010 (166). The ODD protocol provides a standard for describing and sharing ABMs. In 2013 the first extension, the ODD+D protocol (137), added new questions on decision-making process. Then this 2018 extension, the ODD+2D protocol, added section on 'Input Data'. This protocol helps facilitate transparent, comprehensive, and consistent ABM dissemination so other modellers can more easily assess and reproduce the ABM.

that represent typical emigration and immigration hotspots in the Myanmar-Thailand corridor (Figure 26-B). Some of the sub-areas also include non-human entities (or 'proto-agents'), such as a *passport office* (blue squares) or *recruitment agency* (purple squares). The border has three crossing points (one *official*, two *unofficial*) where migrants can move between the origin and destination area. When migrants move between locations or are connected to intermediaries during waiting stages (i.e., recruiters, smugglers, or employers) then the colour of the line showing the migrant's movement or connection represents which migration state they are in (Figure 26-A and Figure 26-C).

A. Agents



B. Environment



C. Environment populated with Agents

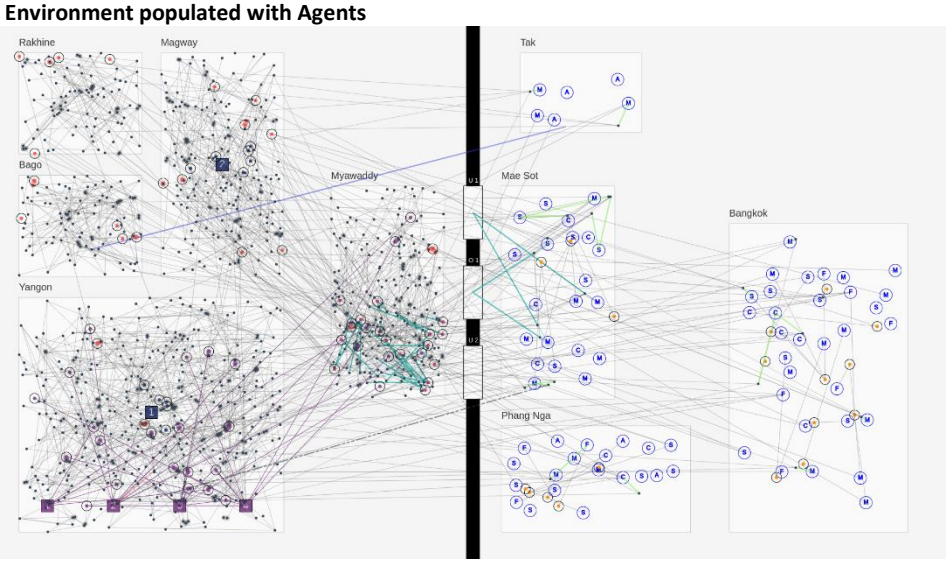


Figure 26. Model agents and environment

Temporal specifications. The model time-steps ('ticks') represent days and the time-horizon (run length) is 1,825 time-steps (i.e., 5-years). The time-horizon was chosen for three reasons: 1) the empirical data informing this model is referencing a period of 5-years from 2014-2019 (215); 2) beyond 5-years, individuals usually experience some kind of life-course event (e.g., marriage, child birth, domestic migration, etc.) that may impact individual attributes included the model, such as their thresholds for an international migration; and 3) given the size and complexity of this model, 5-year runs were achievable within the computational resources available, while still allowing for some of the long-term trends to be included, such as 'repeat' migrations given that the average migration from Myanmar to Thailand lasts between 2-3 years (82).

Model process. The model consists of four sub-models (pre-migration, planning, transit, and employment) that represent a typical migration trajectory. Specific decisions, interactions, and behaviors occur during specific sub-models and, alternatively, some processes, such as plans for arranging migration might occur over multiple sub-models. Figure 27 is the high-level conceptual model that depicts the overarching migration process and some examples of agent actions that occur at different stages/sub-models.

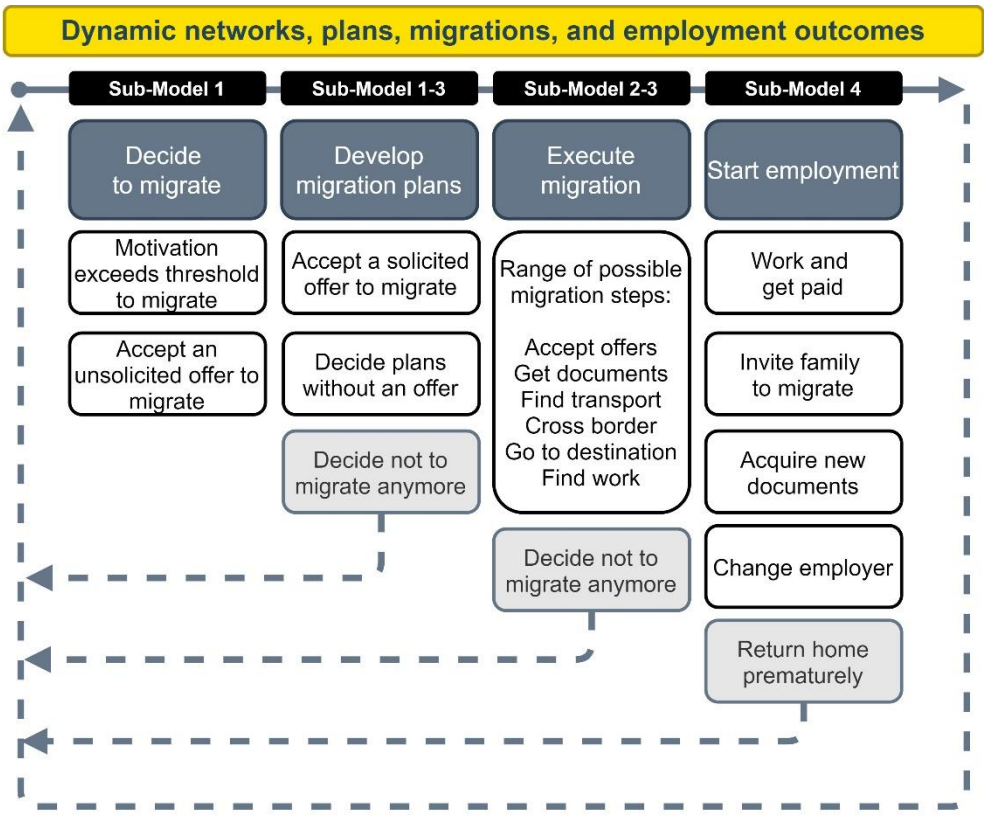


Figure 27. Conceptual model - sub-model process

Theoretical and empirical background. This first iteration of the model consists of simple if-then heuristic rules, and in some cases probabilistic rules. Figure 28 provides an overview of the triangulated theoretical and empirical knowledge that informed the model structure and rules. Multiple empirical sources (arrows) provided contextually specific insights for each level (boxes) of the theoretical framework (see Appendix 8.2 for a version of this figure with theory definitions). The primary empirical source for the model design was a mixed methods social network analysis (MMSNA) study completed in 2019 in Thailand, which was conducted specifically for the purpose of this ABM. This study provided the insights on the agent classes, attributes, and rules of behavior used to inform the model design. The novel study design, tools, and study findings are written up in two separate papers (215, 242). The model was also informed by the findings of the *Capitalising*

Human Mobility for Poverty Alleviation and Inclusive Development for Myanmar (CHIME) study conducted by the University of Sussex Centre for Migration Research (81) and the 2017 Myanmar Living Conditions Survey (MLCS) (260) conducted by the Central Statistical Organization (CSO), United Nations Development Programme, and the World bank.

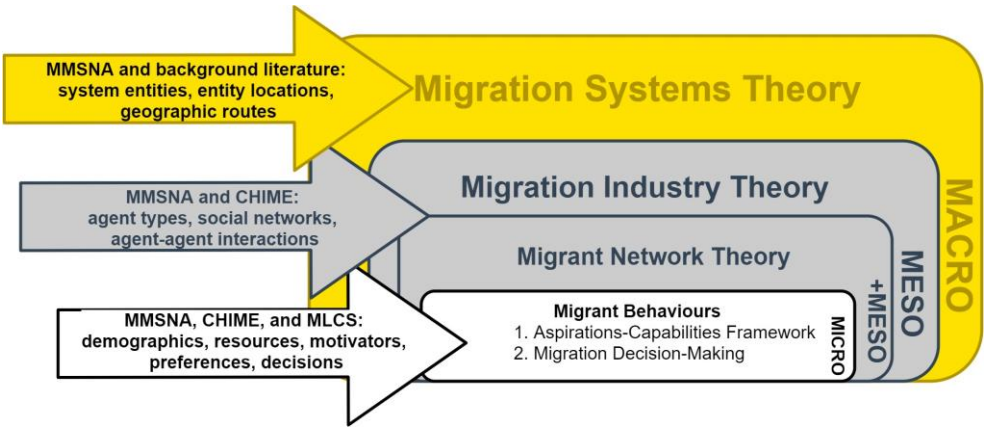


Figure 28. Model theoretical and empirical inputs

Agent actions and interactions. In short, once a migrant agent decides to migrate (Sub-Model 1), based on their financial or social motivations, they then go through a series of steps to plan and execute their migration (Sub-Models 2-3). The migration decisions and plans can be initiated or influenced by other migrant or intermediary agents within a specified social proximity (i.e., family or network contacts) or spatial proximity (i.e., within vision). The most frequent and central interaction between agents in the model is assistance in migration planning, which is formalised in the model as making an 'offer'. Migrants decide whether to accept an offer based on their *preference* (e.g., want to migrate to a specific sector or destination) or resort to choosing randomly in some cases. A migration offer, if accepted by the migrant, then populates some or all properties of a migrant's migration plan (e.g., plan for destination, documentation, employer, etc.), which then will determine the course of action the migrant follows until arriving at a destination (Sub-Model 4). A migrant who is in the process of migrating will

have multiple points at which they may decide to discontinue the migration. Once at destination, a migrant's level of 'precarity' is determined and then can dynamically change during time-steps at destination (e.g., if they change employer). Migrants exhibit some forms of individual and group learning through the model run. For example, a migrant remembers which mediators helped them get to a satisfactory employment outcome, but intentionally 'forgets' mediators that led them to unsatisfactory outcome. These changes to 'memory' of intermediaries can prevent the migrant from re-using those mediators for a future migration (individual learning) or sharing them as contacts for other prospective migrants (group learning). Most migrants return home when they have met a specific financial goal, or in some cases earlier if they are unhappy at destination or forced to return home. There are many other empirically-informed characteristics of the model entities, properties, and rules documented in the ODD+2D protocol for this model (Appendix 7).

Agent Decisions. Decision-making is modelled on an individual level. *Migrant* agents are the most frequent decision-makers. A *Migrant* makes multiple decisions over time in one migration and the range of possible decisions include whether to: migrate; accept an offer; acquire documents before departure; use transport services; pursue an employment option; invite family; acquire new documents at destination; and/or return home or keep working. For example, a *Migrant* decides to migrate by either accepting an unsolicited offer to migrate or by having 'enough' motivation (i.e., "motivation" $\geq$ "motivationThreshold"). The overarching objective that guides a *Migrant's* sequential decision-making is an explicit goal of migrating to a destination and being employed. However, a *Migrant* also aims to do this in a way that satisfies their migration preference. For example, a *Migrant* decides whether to accept an offer by comparing the offer properties (destination, employer, fees, etc.) to their migration preference (sector, proximity to home, presence of social network at destination). Their

subsequent migration decisions are then influenced by which plans they have, as established by the offer they accepted. For example, a Migrant that is using a smuggler for transport will not decide to cross the border 'officially' when they get to the border. Appendix 7 provides additional detail of how decision-making is formalized in the model (A.7.5) as well as the specific conditions, parameters, and in some cases, probabilities for decision rules (A.7.17).

Model implementation and access. The conceptual model and sub-model processes were translated into model code written in JavaScript. The final visualisations have also been written in JavaScript using P5js and D3js visualisation libraries. This method of implementation was chosen, in part, to allow a wider stakeholder audience to access the model in a browser-friendly format that avoids bespoke software access and navigation barriers for novices who could find even a 'low-barrier' freely-available software, such as NetLogo, challenging to navigate. The other objective for the implementation choices was to explore better ways to communicate 'complexity' to non-researcher audiences. The data visualisation libraries available in JavaScript enable more visual customisations to foster model comprehension. These issues of access (browser-view) and comprehension (visual narrative) are critical to ensure the model can be validated and used by a wide-stakeholder group in future intervention work. As statistician and artist, Edward Tufte, advocates, "we shouldn't abbreviate the truth but rather get a new method of presentation." (261) The MyTh MaP-IN model code and ODD+2D protocol documentation are openly available on the CoMSES Computational Model library and GitHub (262).

Initialisation. At initialisation, the environment is setup, and the three agent classes are created with some pre-loaded properties (e.g., motivation, preference, vision) based on specified property distributions, while other properties (e.g., migrations, plans) are left empty to be populated during the

model run. The agent population sizes and distributions across locations were pre-determined in the model code, informed by the MMSNA study. Family links and intermediary-intermediary links were imposed on the model network, whereas migrant-intermediary and migrant-employer links emerged during the model run based on the model rules of interaction.

Additional details on the model design can be found in Appendix 7.

Model outputs

The model analysis used the following four outputs:

> **Output 1 – migrant states** correspond to the sub-model (or stage of migration) that each migrant is in each time-step (pre-migration, planning, transit, employment).
>
> **Output 2 – accepted offers** are counted in each time-step by the type of agent that made the offer (family, facilitators, recruiters, Myanmar document brokers, smugglers, or Thai document brokers).
>
> **Output 3 – precarity score** is a value (0-1) used to assess an individual migrant's level of 'precarity' and then averaged for each pathway.
>
> **Output 4 – sociocentric network indicators** indicate the size (total agents), density (degree of connectivity), and diversity (distribution of agent types) of the model-wide migration network.

Outputs 1 and 2 observe key events in the model (decision to migrate, decision how to migrate) and outputs 3 and 4 are the emergent outcomes. Outputs 2 and 3 are used in the sensitivity analysis (SA) and all four outputs are used in the scenario analysis.

The **precarity score** is a multidimensional outcome composed of eight indicators but calculated into a single aggregate score. The indicators capture the migrant's livelihood pressure, legal status, and the support or knowledge they hold at destination (Table 25). Because the high-level research aim is to explore different migration *pathways* as causal mechanisms for adverse outcomes, we looked at the average precarity score for migrations based on which *pathway* they chose. A 'pathway' is the term we are using to describe the migration trajectory defined by *who* was involved in arranging any part of the migration (i.e., no one, family only, informal intermediaries, or licensed recruiters, again, see Table 25).

Table 25. Precarity score, pathway classifications, and network indicators

Precarity Score Elements	Precarity Score Indicators	IF TRUE* add:
Livelihood Pressure	1. debt to family(t) > wealth(t)	0.1
	2. debt to employer or intermediary(t) > 0	0.2
	3. family wealth is in the lowest 25% of local households	0.1
	4. monthly wages < .09 (i.e., below minimum wage)	0.1
Legal status	5a. has no documents and location is Mae Sot or Tak	0.1
	5b. has no work permit and location is Bangkok or Phang Nga	0.2
Knowledge & support at destination	6. current migration is migrant's first migration	0.1
	7. no family at destination	0.1
	8. no viable, attractive alternative jobs (i.e., vacancy and higher wages and required documents satisfied)	0.1
*IF FALSE then value added is 0		
precarity score(t) = sum of precarity score indicator values that that apply (Score can range from 0-1)		

Pathway Classifications	Pathway Classification Descriptions
Solo	Migration network only includes the migrant
Family	Migration network only includes family member(s)
Informal	Migration network includes at least one intermediary but does not include a recruiter intermediary
Regular	Migration network includes a recruiter intermediary

Network Indicators	Network Indicator Description
Size	Proportion of total agents in the network each year (1-5)
Density	Proportion of 'potential links' present in the network each year (1-5)
Diversity	Distribution of the types of agents in the network each year (1-5)

Precarity scores were dynamic because of possible changes to the indicators while at destination, for example, changes might have occurred through paid/lost wages, increased/decreased household wealth, increased/decreased debt, new/lost documents, influx/departure of other migrants, etc. Thus, to account for these dynamics, we calculated migrant agents' precarity score at each time-step. The analysis explores these scores across the model time-horizon and looks at the dynamics of these scores after aligning the time-frames of each migration's initial precarity score when it is first calculated (end of Sub-Model 3). The average precarity score for each pathway was calculated using the aligned scores.

The rationale for and approach to using 'precarity' as the key outcome of this model is informed by Hannah Lewis's work exploring conceptualisations of migrants' experiences of 'hyper-precarity' (26), Priya Deshingkar's work exploring brokered precarity in the Global South (59) and Myanmar specifically (62, 63), and by the empirical Myanmar-Thailand MMSNA conducted as part of this study (215) (see Appendix 7 for the rationale for each precarity score indicator). Lewis contends that "Understandings of precarity as a condition tend to divide between those who see it as something specific to work under neoliberal labour market conditions and those who see it as a feature of broader life." (26)

For this ABM, we formalise 'precarity' akin to Lewis' definition of hyper-precarity as a feature of migrants' experiences of work and broader life that are dynamic for all migrants and heterogenous across migrants. This framing of precarity accounts for individual and situational experiences of precarity beyond the 'general precarity' of being a marginalised low wage labour migrant in a foreign country, see Figure 29. There are a range of labour migration outcome indicators that have been developed and used in other research, such as the International Labour Organization's indicators for forced labour and unfair recruitment (246). However, this research is interested in the process-oriented exposures that might act as causal

mechanisms for or protection from labour exploitation. This allows us to explore which migration processes ('pathways') put migrants in more *hyper*-precarious positions within a generally precarious system. Furthermore, we have conceptualised this as a multidimensional outcome, because like many other labour migration outcomes (recruitment, health, exploitation), these outcomes are complex and varied in ways that do not lend themselves to dichotomous outcomes, such as 'precarious' or 'not precarious'. For example, in the empirical MMSNA study migrants often explained that Mae Sot has 'different rules' and that it was not as dangerous or precarious to be undocumented in Mae Sot as it would be in areas like Bangkok or Phang Nga that were farther from the border with stricter management of irregular migrants.

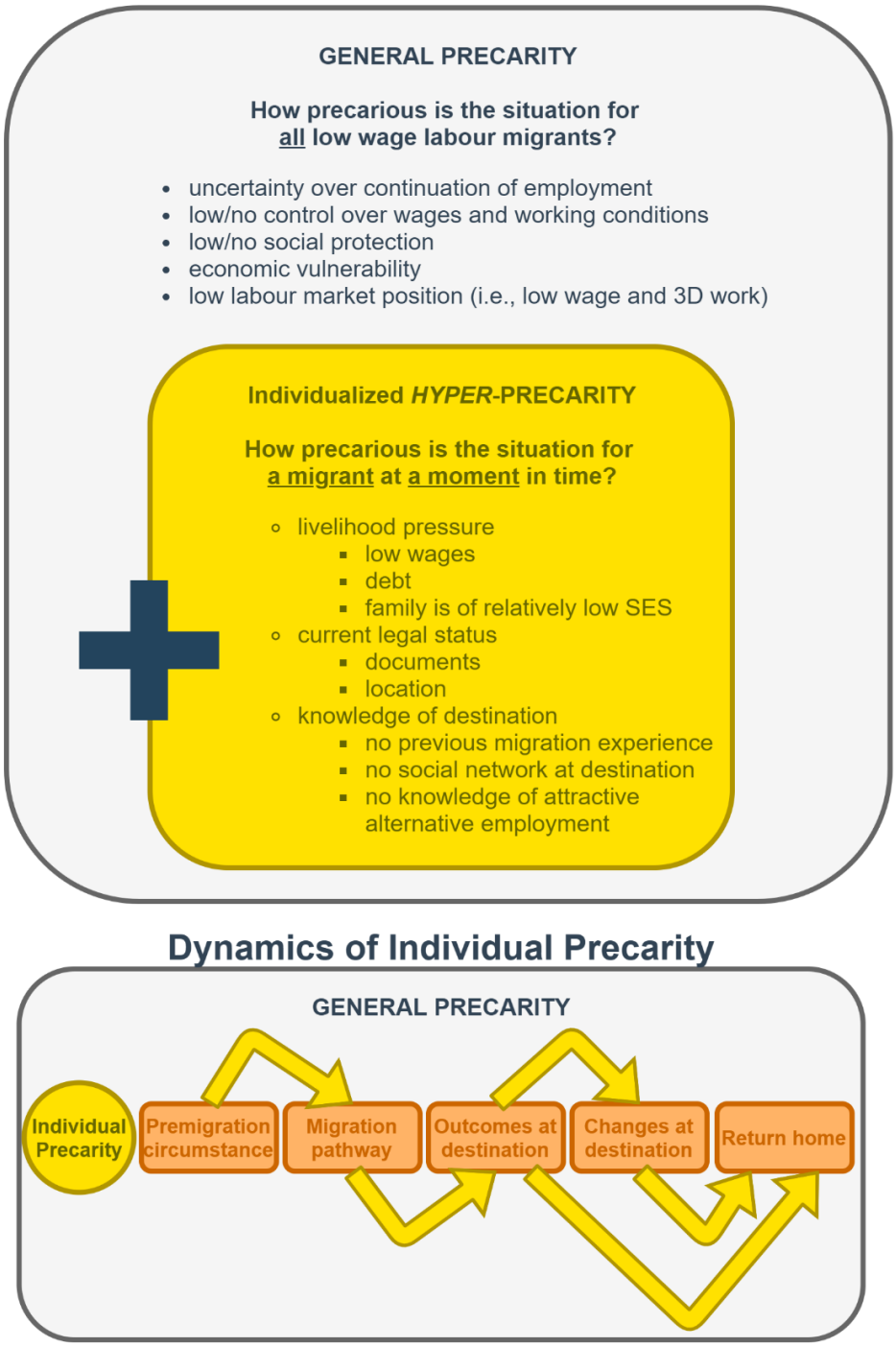


Figure 29. Individual, dynamic, and hyper-precarity

Lastly, the network indicators included the size, density, and diversity of the model's *sociocentric* migration network (i.e., a combined network of *all* the individual migration networks, refer back to Table 25). These indicators were outputted at each time-step and compared across the model scenarios to see how the experiment scenarios (detailed next) impact the network emergence.

Model scenarios

The analysis of the MyTh MaP-IN model compared the four outputs across three scenarios:

1. **Baseline Scenario:** model executed as detailed in the model description.
2. **Experiment Scenario 1 – Highly regulated border:** 'unofficial' border crossings closed.
3. **Experiment 2 – 'Employer pays principle':** recruiter agent 'fees' are set to 0.

The 'experiments' simulate two principles of the internationally promoted 'fair recruitment' model that are explicit to the mediation process simulated in this model: illegal border crossing and recruitment fees. The 'highly regulated border' scenario presents a counterfactual where labour migration is always executed through the legal channels (i.e., formal recruitment or using the 'border pass' system to enter Thailand). The 'Employer Pays Principle' experiment (hereafter, 'EPP scenario') presents a counterfactual where migrant workers do not bear any costs of their formal recruitment process. This principle is a widely advocated for model of recruitment that requires the employer to bear any of the costs of recruitment.

Each scenario was run 50 times using the same 50 random seeds. The data needed for the four outputs were logged for each time-step (n=1825) and exported from each run into JavaScript Object Notation (**JSON**) format, which is a standard data interchange format, for the model analysis.

The results for outputs 1 and 2 (migrant states and accepted offers) are presented as averages of counts from across the runs for each scenario. The results for precarity scores are presented as averages at the individual and pathway level, again across the runs for each scenario. The network indicators are presented as averages and ranges for a smaller subset of Baseline scenario runs (n=10), but the graphical outputs in this paper present an example of one 'typical network' run (identified from the 10 runs) across the three scenarios using the same random seed to present a case-example that was typical to the average findings across all runs.

Evaluation methods

To evaluate the model, we adopted a "gradual, systematic and interactive process of continuous evolution" that mirrors the typical ABM iteration process (263). The model evaluation assessed the quality and reliability of the model at the conceptualisation, specification, and simulation stages. Figure 30 depicts each evaluation step (red-dashed arrows) that transitioned the model from one stage of development to the next. This process and framework for model evaluation was informed by Sargent's paradigm for developing valid systems theory and valid simulations (264). The model evaluation took place at two stages, during the model building ('pre-simulation') and once the model was built.

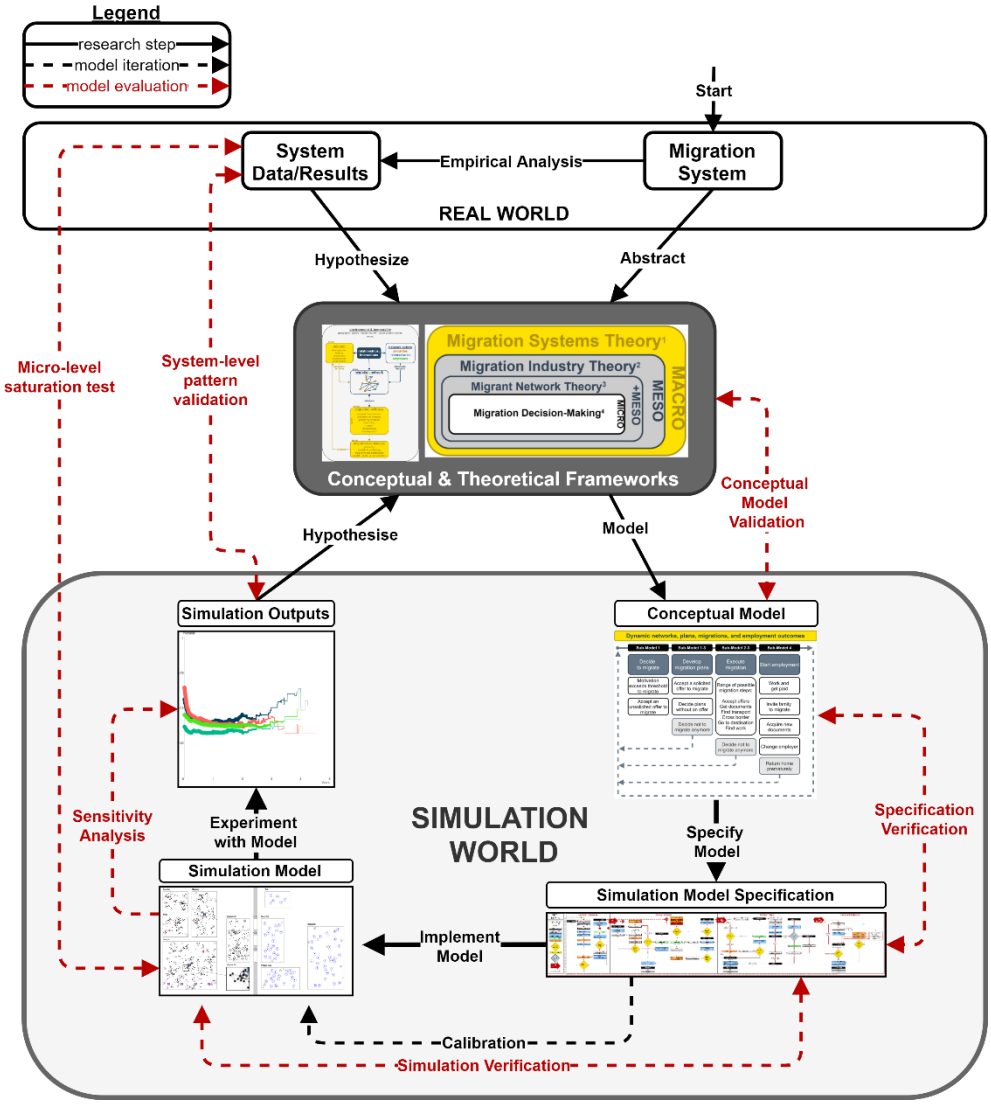


Figure 30. Model development and evaluation

Model Evaluation – Pre-simulation stage

This section presents the conceptual validation and specification verification that took place during the model design and building stages.

Conceptual model validation

Following Sargent's description of *conceptual model validation*, we endeavoured to determine whether the conceptual model (refer back to Figure 27) was a "reasonable representation" of the migration system, actors, and processes, as described by the theoretical and conceptual frameworks that guided the study design (Appendix 8.2) (264). Led by the model purpose and frameworks, we verified that the conceptual model addressed: 1) the system's micro *and* meso levels (confirmed: individual decision-making, network interactions); 2) relevant actors and behaviours (confirmed: multiple actor types, heterogenous offers, heterogenous decision making); and 3) dynamic migration stages (confirmed: progression of sub-models and respective behaviours). Both the strong theoretical base and lead modeller's familiarity with the empirical data through data collection and analysis produced a conceptual model that we determined sufficiently represented the system process. Additionally, the conceptual model underwent 'face validity' checks by the two co-authors (LK, CZ), who each have extensive subject expertise and were not directly involved in the model design. Both experts verified that the model sufficiently captured the phenomenon of labour migration (264, 265). We determined that validating the conceptual model in this way was a prerequisite to moving on to specifying the *computational* model.

Model specification verification

For model specification, we began by explicitly detailing the model-based rules and rationales (Appendix A.7.13). These rules are an evolved state of the conceptual model that provided instructions from the modeller to the programmer about how to specify and build the ABM. According to Wilensky

and Rand, “verification is the process of ensuring that a computational model faithfully implements its target conceptual model” (152, p. 161) , and it is carried out during the design and construction steps of the model development. We developed two graphical representations of the computational model to guide the *specification verification*. That is, this process was used to check that every element of the conceptual model and rules were sufficiently addressed in the specification of the ABM programming instructions. The first guide, partially represented in Figure 31, was a Unified Modelling Language (UML) diagram of the model entities, their properties, and links between entities (e.g., agent entity ‘parent’ to an object entity). The second visual guide, Figure 32, was a schematic of all the rules in the order of execution across all four sub-models. Together with the documentation of the model-based rules, these diagrams provided the instructions for the programmer about how to code the *computational* model. The lead modeller constructed the conceptual model, and the simulation specification diagrams, which eased congruent translation between the empirical and theoretical insights, conceptual model, and computational model.

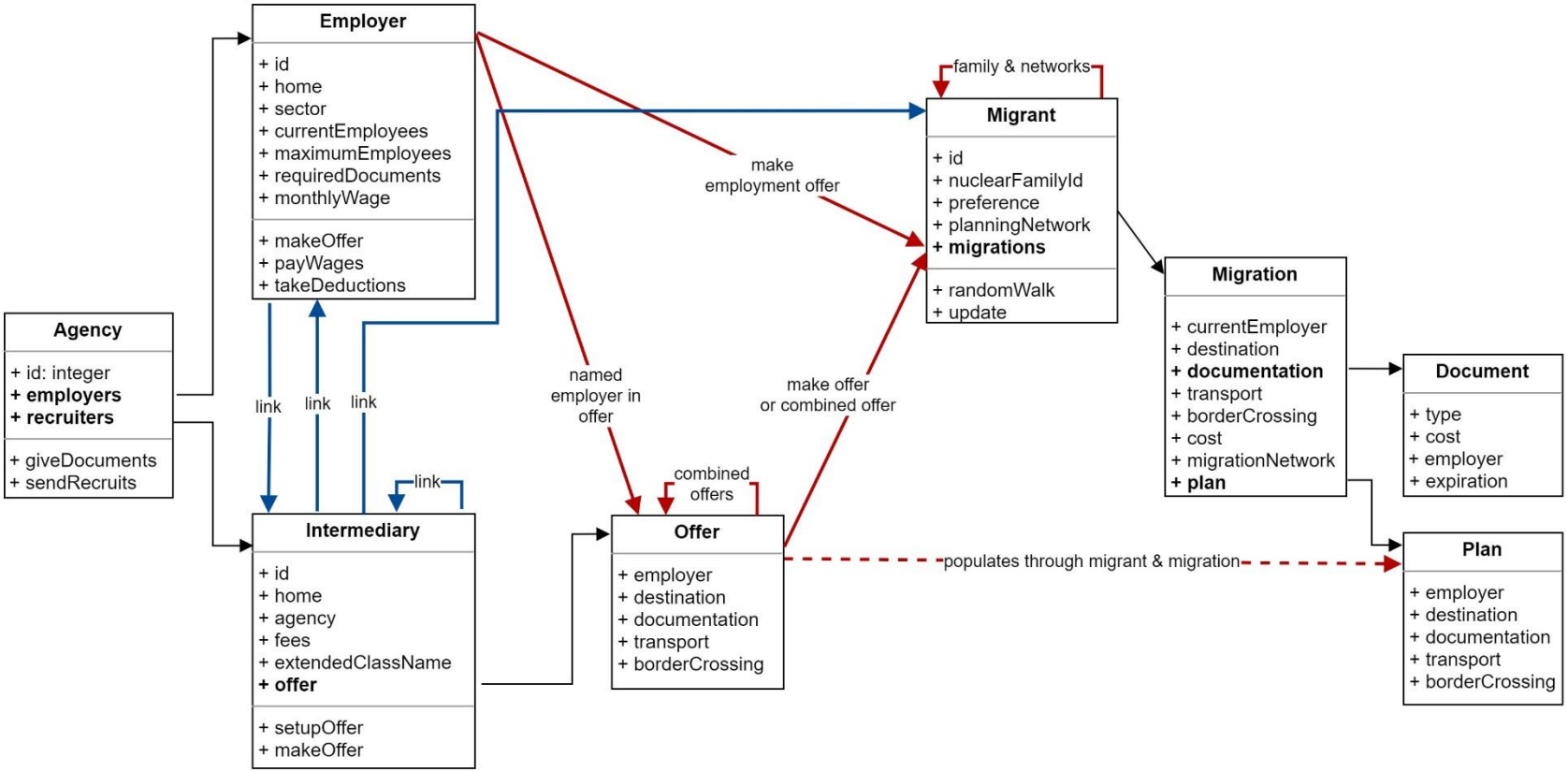


Figure 31. Partial UML diagram - migration ‘offers’ and 'plans'

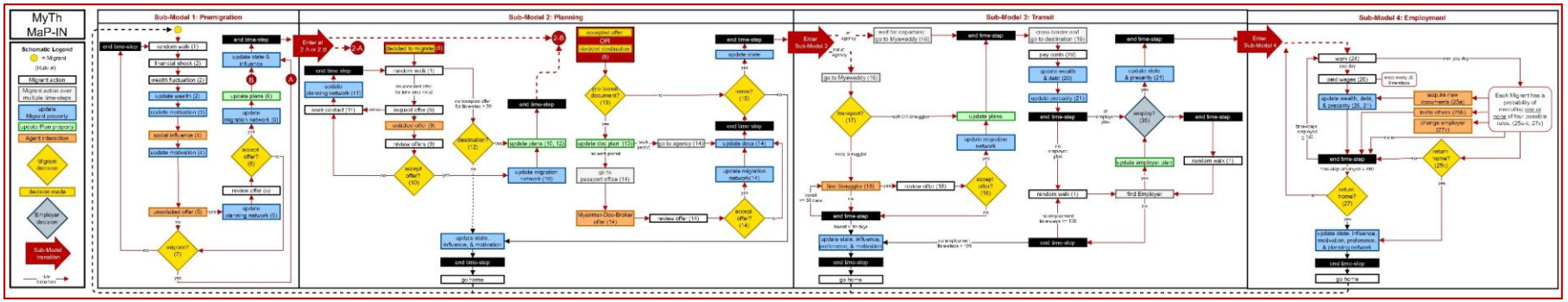


Figure 32. Computational model schematic with four sub-models

Migrant states

In Figure 33, the three graph planes represent the full migrant population (n = 1,000) and the four-coloured areas depict the average proportion of the population in each migrant states (i.e., average of 50 runs for *each* scenario). Because the model is initialised without any 'history', for example, no migrants at destination or migrant-intermediary links, there were no migrations in the first ~6-months. During this time, the agents are interacting, making connections, and experiencing changes in their motivation to migrate. Then at ~6-12-months migrations began, and across all three scenarios, this time frame had the highest rates of initiated migrations (coral-coloured area). This increase tapers off, likely because most migrants with lower 'migration thresholds' (i.e., indicator that represents their willingness to migrate) had all started migrating and the remaining population had higher thresholds. For the remainder of the run, the remaining population migrated at a lower but steady rate. Repeat migrations (i.e., migrant agents that have returned from their migration and started a second migration) also contributed to the steady rates of new migrations. Looking across the scenarios, there were not significant differences in the dynamics of migrant states. The one exception is that in experiment 1 (i.e., highly regulated border) about half the percentage of migrants entered *employed* state (~1% of the population of migrants on average across the time-steps) compared to the baseline or experiment 2 (~2-2.5%), despite there being similar rates of initiated migrations. This imbalance is due to the high rates of migrants that chose irregular pathways and could not progress beyond the only open border crossing (i.e., 'official' crossing). For all three scenarios, the proportion of the population in planning, transit, or employed state at any given time-step was <25% of the total migrant population.

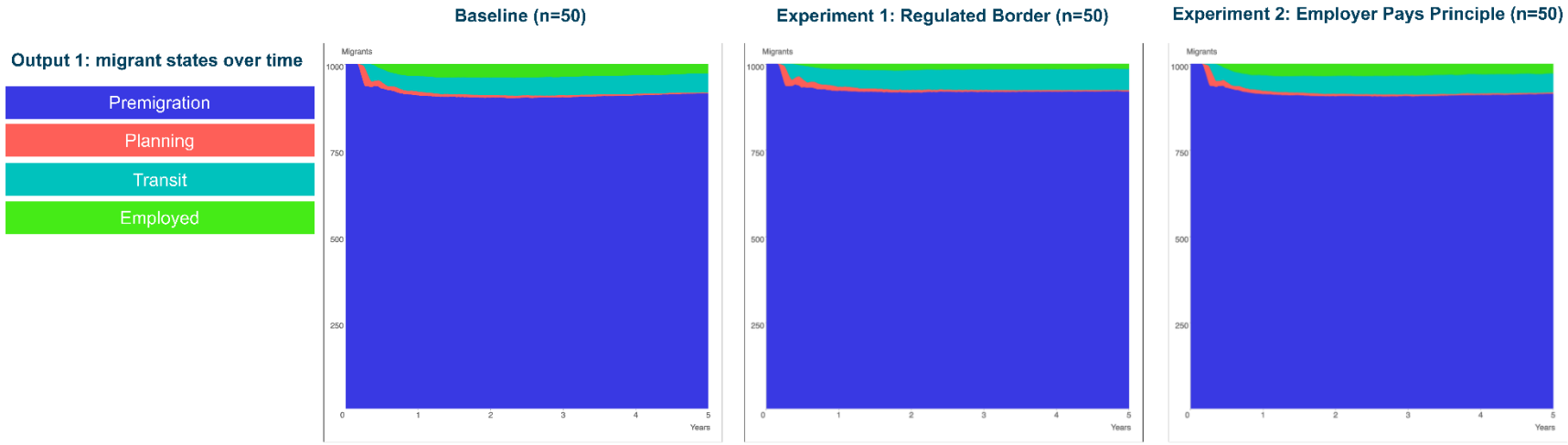


Figure 33. Migrant states over time

Accepted offers

The second model output is the cumulative accepted offers from each type of agent that can make migration-related offers (i.e., family members, facilitators, recruiters, Myanmar document brokers, smugglers, and Thailand document brokers). This output is an indicator of the distribution of these intermediary or family agents who are involved in individual migration networks. The trends for the Baseline and EPP scenario showed similar dynamics that reflected that facilitator, Thai document broker, and family offers were the most accepted offers. Thai document broker offers surpass facilitator offers near the end of the model run, indicating an increased demand for new documents occurred at a faster rate than new migrations were being initiated by facilitators, which likely represents those migrants choosing to stay for longer periods and seeking documentation during their stay (see Figure 34). Offers from recruiters and smugglers also show a steady rate of increase but at a less sharp incline. Finally, Myanmar document brokers are the least frequently accepted offers in these simulation runs. The most notable difference between these scenarios is the extremely high frequency of facilitator- and smuggler-accepted offers in the regulated border scenario. This reflects the same issue as the drop in *employed* migrants for the previous output, which is that fewer migrants using these irregular pathways can cross the border. However, these migrants' preferences and social networks are unlikely to change and thus any repeat attempts would lead to newly accepted offers by similar intermediaries. Therefore, this result is not a sign of increased demand so much as increased barriers in facilitator or smuggler coordinated pathways. This iteration of MyTh MaP-In did not have the data or insights about how migrants adapt to failed migration attempts but could be added in future iterations given the right empirical insights. The regulated border scenario also presents a decreased frequency of accepted Thai document broker offers, which makes sense given that most migrants arriving

in Thailand for this scenario will have already had some form of documentation to cross the border. However, what is striking is that there is still some demand for documentation services *after* arrival, which likely suggests migrants who lose their documents due to employment changes or those seeking new documents to extend stays at destination. Changes may be caused by their dissatisfaction with their current employment, a desire to improve employment circumstances, *or* the possibility that migrants did not achieve their savings goals before their documents expired.

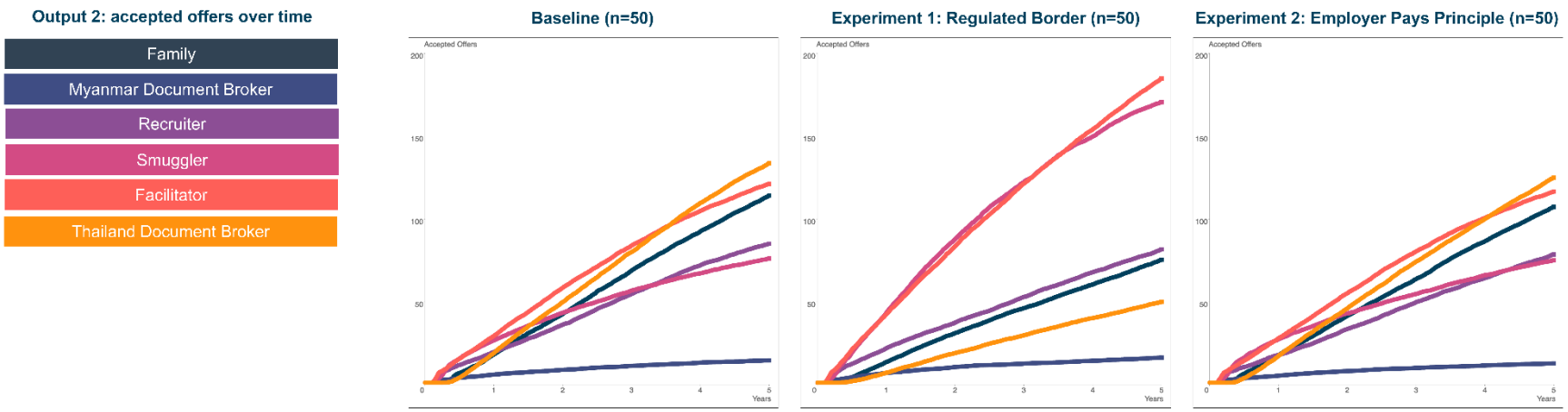


Figure 34. Accepted offers

Pathway precarity

The primary outcome of interest was the 'pathway precarity' (individual migration precarity scores averaged by pathway type). We will begin by presenting the findings for the Baseline scenario and then compare across the three scenarios.

Baseline scenario

First, we explored the individual precarity scores of all migrations across the model time-horizon, see Figure 35 (top row). The precarity score is calculated at the end of Sub-Model 3 when migrants have arrived at their destination. The graphs for the solo and regular pathways show that solo pathways arrive at destination sooner in the model run (year 1) compared to the regular migrations which do not occur at greater frequency until later (~year 1.5). This is most likely attributed to the time it takes to plan and execute regular pathways compared to self-directed routes. The top row of graphs also depicts the range of precarity scores realised for each pathway. The low and high of these ranges are consistent across the model time-horizon but differ by pathway. For example, informal and regular pathways have higher maximum precarity ranges compared to solo or family migrations. This can be most clearly observed in the final graphs of Figure 35 (last row) where the pathway precarity scores are merged into one plane.

We also explored the dynamics of these ranges for the pathway time-lines irrespective of the model time-horizon. To do this, we graphed the precarity scores as if they all started at the same time-step instead of how they were staggered throughout the model time-horizon (i.e., we aligned the migrations by their individual timelines not where they took place in the model run), see Figure 35 (middle row). We noted the same trend in ranges when comparing across pathways, regular and informal pathways have higher maximum

precarities, but these graphs also indicate that across all pathways, precarity is highest in the early time-steps at destination and tends to decrease with time spent at destination, apart from a small minority of outliers. The regular pathway has more of these high range outliers throughout the model run than the other three pathways.

Figure 35 (last row) takes the run average of these aligned precarity scores for each pathway and then the average across the runs to plot a single line for which the thickness reflects the total runs that contributed averages at that time-step (i.e., runs that still had migrations continuing up to that time-step). In these graphs, we again observe the higher precarity score trends in the informal and regular pathways, but we also observe more clearly that the initial precarity scores for informal and regular pathways start at the relative maximum ranges and then have a significant drop in the first ~6-months at destination, which then steadies to more consistent fluctuations after that point. This initial decrease in precarity score is true for solo and family pathways as well but at lower starting precarity scores. The regular pathway sees a thinning of the line at 2-years, which is when migrants who are still with their original employer lose their work permit and potentially go home. The remaining runs that have ongoing migrations after this 2-year point may present higher precarity scores on average because those migrants that did not have an expired work permit exactly at 2-years were likely to be those who found ways to change employers during the 2-year period so they could achieve higher wages or more attractive working conditions.

Across all the runs and pathways, most migrations end within the first 3 years, and thus there is a plateauing of the precarity score near the end of the 5-year plotted line. For the solo, family, and regular pathways, the migrations that go beyond 3-years are, on average, more precarious. These precarity levels are

likely due to situations akin to ‘bonded labour’ where a migrant has debt to their employer or industry and cannot return home or change employers. The exception to this year 4-5 increase is informal pathways, which show a lower precarity average. While there were not huge differences between pathway scores for a significant length of the run, the family pathways were consistently the least precarious and regular migration pathways were consistently the most precarious across all three scenarios.

Figure 35. Pathway precarity over time

Scenario comparison

Looking across the three model scenarios, there are a few observable differences in pathway precarity (Figure 36). In experiment 1 (i.e., highly regulated border), all pathways have a lower average initial precarity score than in the baseline scenario, but as noted in the 'migrant states' scenario comparisons (refer back to Figure 33), this is within the context of an overall reduction in migration that excludes all undocumented migration (i.e., migrants needed either short- or long-term documentation to enter via the official crossing). For family and solo pathways in experiment 1 (see Figure 36 – bottom row), the initially lower average precarity jumps up in year-1 to a similar precarity to the baseline scenario. This increase in precarity is likely due to the expiration of any temporary documents that enabled the migrants to use these more irregular pathways to *enter* Thailand, but not for long term work. Where the first experiment reduced over all migration and reduced the initial precarity for all four pathways, the second experiment scenario (Employer Pays Principle, i.e., no recruiter fees) did not have a significant impact on the frequency of completed migrations and had a more targeted influence in reducing the precarity of the regular pathway (from an initial ~0.58 to ~0.50). The average precarity of the regular pathway in experiment scenario 2 also stayed consistently lower across the model runs and did not include the high plateauing of the average between years 3-5.

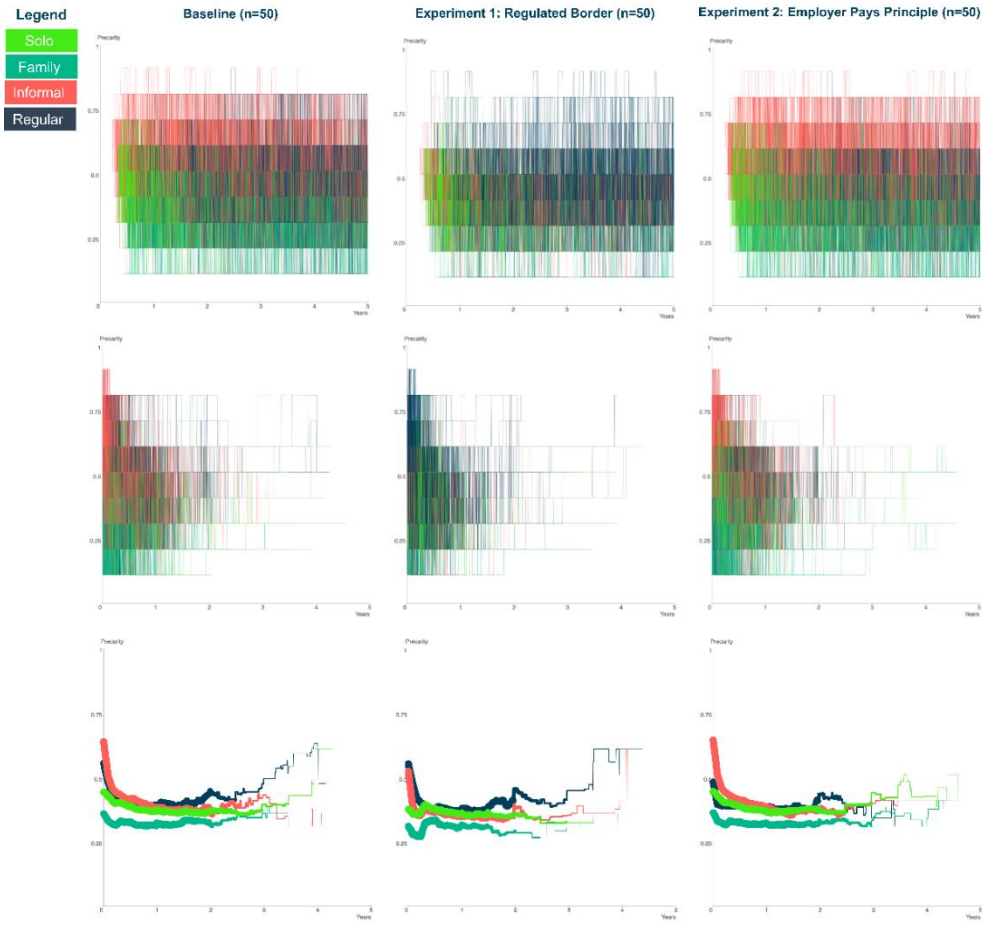
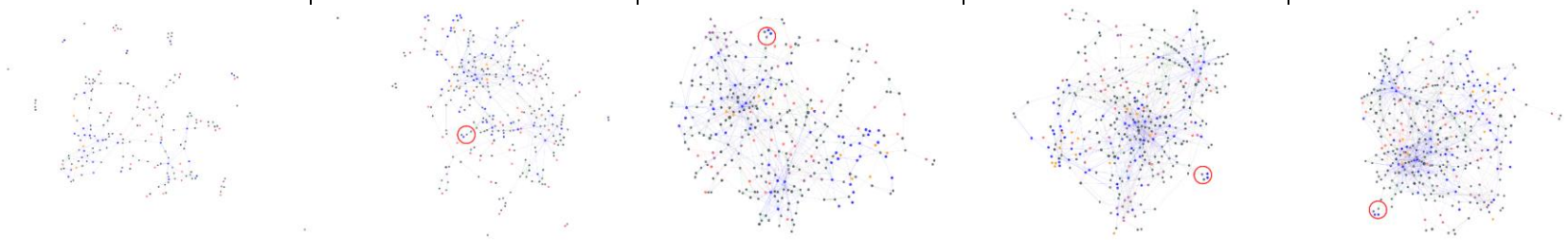


Figure 36. Pathway precarity scenario comparisons

Sociocentric migration network

Lastly, we also qualitatively explored the emergent sociocentric migration network, which is the network of all agents that migrated or were involved in a migration. The aim was to see what observations could be made about how the system's network evolves across the model time-horizon. To do this, we looked at the proportion of the population (n = 1,172 i.e., migrants, intermediaries, and employers) present in the network, the network density, and the diversity of actors in the network. We executed a smaller set of baseline runs (n=10) to find the average and range of network compositions to identify a single run that could be used as a 'case network' to explore. We compared the network composition of this single run at 5 time points. Table 26 presents visuals and indicators for the case network's composition over the 5-year run. This network includes migrant-migrant, migrant-intermediary, intermediary-intermediary, and intermediary-employer links that occurred within the context of a migration (i.e., if two intermediaries in the network knew each other but were not linked in relation to any specific migration then that link was not added), and the network includes all family links between any of the agents regardless of involvement in specific migrations. As expected from outputs on initiated migration, the network goes through it greatest growth in years 1 and 2 and the growth slows in the later years. The year-1 network shows many 'floating' clusters (the result of self-motivated or intermediary-initiated migrations) that are completely linked into the network by year-5. As the network evolves, patterns of clusters emerge around families and employers, often with families working at the same employer. The diversity of agents is fairly consistent across the model runs, with some decrease in proportions of facilitators and smugglers and increased presence of employers and Thai document brokers, again highlighting the dynamics after arrival which may link migrants to new employers and new documents, separate from their initial pathways of entry.

Table 26. MyTh MaP-IN sociocentric migration network at 5 timepoints

	Year 1	Year 2	Year 3	Year 4	Year 5
5-year network sociogram[3]					
size	194	297	341	366	379
density	1.63%	1.47%	1.50%	1.60%	1.68%
migrants	65%	63%	65%	64%	65%
recruiters	6%	7%	6%	6%	6%
facilitators	8%	7%	6%	6%	6%
smugglers	6%	4%	4%	4%	3%
MDB[1]	1%	1%	2%	2%	2%
TDB[2]	2%	2%	3%	4%	3%
employers	13%	16%	15%	15%	15%

[1]Myanmar document brokers; [2]Thai document brokers

[3]The network sociograms are force-directed graphs, which means the nodes move location in response to changes in network composition. The red circle around one specific cluster of nodes is a point of reference for the viewer to position the network visual in relation to the one before or after.

Simulation verification

The aim of *simulation verification*, or 'internal validation', is to manage any significant disparity between the conceptual model and programmed model (266). At this stage, our explicit objective was to identify and correct any errors or artefacts (i.e., unintended assumptions influencing the outputs) in the model code. Because ABMs are a method to study emergence, it can be difficult to distinguish between 'unexpected' outcomes resulting from model complexity versus from an error or artefact in the code (266, 267). Highly complex ABMs, such as this one, exacerbate this challenge since it is not feasible to assess the patterns of all the interactions and decisions being executed or the many 'mid-process' outcomes (i.e., decisions outcomes, pathway choices). We attempted to navigate these challenges and conduct achievable yet thorough verification using two strategies:

1) **Quality checked model code**: In a similar style to 'paired programming', the programmer (LD) and modeller (AM) completed the model building stage in unison to minimise the occurrence of errors. As part of this process, the corresponding rule numbers from model documentation (Appendix 7.13) and semantic annotations were added to each unit of code to explain the purpose of those lines of code. The programmer and modeller reviewed the full model code line-by-line to identify and correct two types of errors
    - **Semantic errors –** typos or naming errors. The annotated code allowed us to easily check that all the rules were included and executed in the right order. The final model code was compared to the sub-model specification diagrams (refer back to Figures 31 and 32) to confirm the full model process was included in the code.

- **Logical errors (Step 2) –** rules not executing what they are supposed to. Each procedure or function (i.e., block of code) was compared to the description of the model-based rule it corresponded to (per the annotations) to confirm that the 'essence' of the rule was adequately represented, accepting that natural language and heuristic rules will not always be a one-for-one match to programmatic code. As part of this process, the programmer 'read' the final code logic to the modeller who confirmed whether it was the intended logic of the model-based rule.

2) **Explored simulation runs:** The second strategy was to progressively verify the sub-model executions and outputs in four stages looking at sub-model(s) 1, 1-2, 1-3, and 1-4. It was not within the scope of this work to verify sub-models 2, 3, and 4 in isolation or to use formal methods of verification, such as model replication or exploring multiple updating techniques [45], both of which are promising methods for future evaluation of this model. At each stage, we explored a small sample of simulation runs (n=10) to assess any unexpected frequencies of select rules and outcomes to identify any artefacts:
    - **Artefacts (Step 3) –** unintended assumptions implicit in the model design. We reviewed the simulation runs to perform 'expected outcome alignment'. First, we looked to see if any of the rules were 'over' or 'under' firing relative to expectations based on empirical insight. The modeller outlined the select rules and outcomes to review based on their importance in the model process and the programmer and modeller jointly reviewed the data logs and outputs from the runs to check the frequency totals and ranges for

key ‘events’ (i.e., rules firing) or outcomes (e.g., migrants changing states, financial shocks). Unexpected observations were reviewed as possible artefacts and model rules were calibrated as needed.

The full list of errors and artefacts observed during simulation verification are detailed in Appendix 8.3. Table 27 presents examples of a semantic error, logical error, and artefact that were identified and corrected during verification.

Table 27. Model verification – examples of errors and artefacts

Type	Specific example	Action taken
Semantic error	Multiple names used for *Document-Brokers*	The model code was reviewed using the inventory of all the agent properties included in the ODD+2D documentation to ensure all naming was consistent *between* the documentation and the code and consistent *throughout* the code.
Logical error	Family was sending employer offers without vacancy.	A condition was added that a family member only includes ‘employer’ in the offer if their employer has vacancy, otherwise the offer is for ‘destination’ only.
Artefact	Recruiter pathways were the most frequent pathway, contradicting both the empirical evidence and the intended function of the model rules.	Recruiter offers were unintentionally over-represented because a single recruiter was sending an offer for *each* possible offer combination they owned. To ensure each recruiter only contributed one offer to a single migrant’s options we added a filtering stage to determine which of the recruiter’s potential offers was a best option for that migrant and was added to the migrant’s options.

Because the modeller and programmer worked closely at all stages of the model development and build, there were few semantic or logical errors identified during this verification process. We explored the simulation runs and outputs to identify any final outstanding semantic or logical errors or, more importantly at this stage, any model artefacts. To do this, we executed the following steps three times: running the simulation (n=10), outputting select data on rules firing and outcomes, reviewed outputs, noted any anomalies, referenced the conceptual model and empirical data, and calibrated any changes needed.

For example, migrants were acquiring pre-migration documentation and crossing the 'official' border at unexpectedly high rates. We identified this was due to two unintended assumptions in the way a migrant's 'documentation preference' worked as well as over-represented recruiter offers. These sorts of 'unintentional assumptions' in the model design were identified and, if identified, removed at this stage.

Saturation test and pattern validation

Until recently, most ABMs have not been validated rigorously, conceptually *or* operationally, and there continues to be many challenges to validating models (e.g., lack of suitable empirical data to use, highly complex models, validating at various levels, validation techniques using theoretical or qualitative insights) (268, 269). Edward Chattoe-Brown, a prolific agent-based modeller, argues that validation is "a more fundamental challenge to the quality of a model than calibration" and that the reliability of models depends on whether the plausibility of model assumptions map intuitively to the plausibility of model outcomes (270). Our approach to evaluating this model aimed to make best use of the empirical data available, which included applying different techniques (qualitative and quantitative) to different levels (micro- and system-) of the model to increase confidence in the model design and outputs.

Considering the model purpose, to describe the system and explore possible causal mechanisms, the validation at this stage is concerned with 'replicative validity' (*Can the model reproduce known behaviour of the real system?*) and 'structural validity' (*Does the model internally behave similarly to the real system?*) (271, 272). At present, there is no real-world data available to validate the internal behaviors of the model and process outcomes (such as how many migrants took each type of pathway, frequency of intermediary interactions, etc.). However, we aimed to perform some intermediary steps to evaluate the

model process, as detailed by the model design and informed by the primary analysis of the MMSNA study. Therefore, at this stage, we resorted to a test of saturation for the model's internal processes (hereafter, 'micro-level saturation test') before a first attempt to validate the model by comparing patterns in the outcomes to other empirical research (hereafter, 'system-level pattern validation'). The MyTh MaP-IN model validation did not test 'predictive validity' since the model did not aim to predict outcomes. The model evaluation addressed three levels of representation, described in Table 28.

Table 28. Model saturation test and pattern validation

Level of representation		Elements	Method
Micro-level saturation test	Entities, properties, and rules	• Preference • Offers • Migration initiation • Plan decisions-makers	Inductive analysis that purposively compares the interview data from a set of randomly partitioned interviews (not included in the primary MMSNA study) to the ABM's micro-level model elements listed in this table.
	Processes	• Network emergence • Pathway	
System-level pattern validation	Patterns	• Total migrations • Total financial shocks • Frequency of pathways	Comparison of simulation event or outcome trends with similar quantitative empirical findings.

Micro-level saturation test. At this stage, we considered the model entities, properties, and rules, as well as the overall process individual migrant agents followed. To do this, we randomly partitioned 15% of the interviews in each data collection site (15 interviews total across the 3 sites) from the MMSNA study and excluded those interviews from the primary MMSNA which informed the model rules (215). ABMs can and *have* been validated using qualitative data sources, albeit usually in the form of stakeholder feedback (273, 274), whereas this study used a subset of the same dataset that informed the model design to

check the saturation of the original model assumptions against the narratives and behaviors described in the partitioned interviews. After completing the model design and build, the partitioned interviews were inductively analyzed using the *a priori* themes (see micro-level 'elements' in Table 28) to see if the ABM rules and simulated pathways observed in the runs accounted for the actions, interactions, and events in the partitioned interviews. This entailed checking that the partitioned interviews: 1) confirm the model design choices; 2) do not indicate any critical missing elements that could feasibly be integrated; and, importantly, 3) that none of the interview narratives contradicted the model design choices.

During this process, we noted that most of the interview narratives related to migration preferences, initiation, offers, planning, and decision-making were already included in the model specification (e.g., entities, rules). Table 29 highlights some of the data extracted during the micro-level saturation test. None of this analysis contradicted existing rules, but a few of the extracted data points (highlighted in yellow) included interactions or agent types that were not included in the current iteration of the model. Most of these excluded model elements were already captured in the preliminary analysis, and addressed in the MMSNA findings paper (215), but were intentionally excluded during the model design to keep the model as simple as possible (following the ABM community's adopted KISS principle – 'Keep It Simple, Stupid (152)). These intentional exclusions represented rarer occurrences or outlier events (e.g., an official passport clerk linked a migrant directly to a recruiter, a migrant was primarily motivated by education not employment).

Additional deductive analysis of these partitioned interviews (i.e., looking for new patterns across the interviews that were not named by the *a priori* themes) highlighted several themes that were already integrated into the model design

and a few themes that were not included in this iteration, see Table 30. Due to limited data on some of these themes and our attempts to limit model complexity beyond the scope and purpose of this work, neither of the two themes identified as ‘not included’ were added at this stage.

Table 29. Micro-level saturation test- inductive analysis of partitioned interviews

The details highlighted in yellow are agents, behaviours, or interaction *not* included in current model rules. All other details in this table were identified as being addressed in the current model and not conflicting with any of the model rules.						
Entities, properties, and rules					**Process**	
	Migration preference	**Initiated by:** motivation (M) unsolicited offer (UO)	**Offers: solicited (SO) unsolicited (UO)**	**Plan decision makers**	**Network emergence** **(o)** = at origin; **(d)** = at destination ➲ = actor linked migrant to next actor ✚ = both actors present	**Pathway**
1	job only	M-financial	SO – facilitator + recruiter	facilitator chose recruiter, recruiter chose plans	facilitator (o) ➲ recruiter (d) ➲ employer (d)	regular
2	job only	M-financial	SO – family SO – recruiter	family chose recruiter, recruiter chose plans	aunt (d) ➲ recruiter (d) ➲ recruiter (o) ➲ employer (d)	regular
3	sector	UO-family	UO – family SO – smuggler	family chose destination and smuggler, migrant chose employer post-migration, boss chose document broker	mother (d) ✚ friends (d)	informal
4	sector	UO-social	SO – social	friend chose destination, friend chose employer after arrival	friend (d) ➲ supervisor (d) ➲ employer (d)	informal
5	join family	M	SO – family	father chose destination	father (d) ✚ mother (d) ➲ employer (d)	family
6	join family	M-financial & social	SO – facilitator	facilitator chose transport, facilitator's contact chose job	neighbour (o) ➲ acquaintance (d)	informal
7	high wages	M	SO – recruiter	migrant chose passport, passport clerk chose recruiter, recruiter chose destination and employer	passport clerk (o) ➲ recruiter (o) ➲ recruiter (d)	regular
8	high wages	M	SO – recruiter	recruiter chose plans, husband at destination changed plans after arrival	recruiter (o) ➲ planned employer (d) but husband (d) ➲ unplanned employer (d)	regular
9	join family	UO- family	UO – family SO – document broker + smuggler	husband and in-laws chose destination, in-laws chose documentation and transport	husband (d) ➲ mother-in-law (d) ➲ Myanmar document broker (o)	informal

10	join family	M-financial	UO – family	family chose plans	family co-migrants (o) ➲ sister (d) ➲ employer (d)	family
11	join family	M-education UO-family	SO – family	father chose transport, mother chose employer	father (d) ✚ mother (d) ➲ employer (d)	family
12	join family	M-financial	SO – family	sister chose destination and transport	sister (d) ➲ smuggler (o)	informal
13	none	M-financial	solicited family	family chose destination, social network chose job, employer chose document broker	father (d) ✚ social (d) ➲ employer (d)	family
14	social network	M-financial	solicited family	brother chose destination, extended family chose employer	brother (d) ➲ brother's in-laws (d)	family
15	social network	M-financial UO- social	unsolicited social	social chose transport, rest planned post-migration	social (o) ➲ acquaintances (d)	family

Table 30. Micro-level saturation test - deductive analysis of partitioned interviews

Theme identified	Comparison to model design
The MOU regulated pathway takes longer and is prone to delays.	**Included:** The model includes two implicit delay periods for MOU migrants: 1) while waiting for documents; 2) while waiting for the agency to meet their 'minimum' recruits before sending the migrants to destination.
Migrants plan to stay working until they have reached a financial goal. Migrants struggle for multiple months to pay off debt before saving or remitting.	**Included:** Migrants final wage payment is subject to deductions and debt is subject to interest. Migrants' ability to accrue wealth depends partly on having no debt to industry. Migrating home depends on meeting savings goals *and* being able to pay off any social debt on their return. **Included indirectly:** Remittance is not explicitly formalised in the model, but because nuclear family wealth is used as an indicator at origin, any increase to a migrant's wealth increases their family's relative wealth which is a proxy for remittances.
Many migrants change employment after some time at destination, but some choose not to for fear changing will cause them problems.	**Included:** Migrants have different conditions for their decision to change employers (e.g., comparing wages between current and alternative work). Changing employment has the potential to incur financial loss (lower overall paid wages) or lost documents, which are the kinds of 'problems' migrants referred to in the qualitative narratives.
Documentation status is dynamic. Documents can expire or get lost, but new documentation can also be acquired after arrival.	**Included:** Migrants' documents have expiration dates in the model. Documents can also be lost after changing employers. Alternatively, migrants can use Thai Document Brokers to acquire new documents after arrival.
Migrants notifying other migrants about vacancies, no vacancy stopping migrants from getting jobs.	**Included:** Vacancy is one condition for being offered employment by an employer agent. Family members at destination sometimes include 'employer' in their offers if there is vacancy at the time of offering.
Undocumented migrants can find work without an intermediary.	**Included:** Migrants that arrive at destination without employment can look for an employer after arrival and not all employers require documents to make an employment offer.
Migration motivation was sometimes more influenced by positive encouragements than it was by any negative discouragements.	**Not included:** We did not have enough evidence to explain how positive versus negative influences might impact decision making differently, for different agents, in different contexts. Since we did not have these insights, we resorted to modelling that negative and positive social influences had similar proportional influence on motivation to migrate.
Migrants migrate onward to Bangkok from more rural or broader-areas in Thailand.	**Not included:** To minimise complexity beyond the scope of the research question, we limited the model to international migration to a single destination, excluding all domestic migration and 'onward migration' within Thailand. This is an area we are considering for future iterations.
Inviting others once settled.	**Included:** Employed migrants (in Sub-model 4) can invite family members if certain conditions are met.

System-level validation. After completing the saturation test, we endeavored to perform a first step in validating the model by exploring aggregate patterns of outcomes at the system level. At this stage, we qualitatively compared quantitative empirical findings on Myanmar-Thailand migration trends from multiple survey sources with the baseline simulation observations. Due to a scarcity of reliable population level data, especially longitudinal data to compare the dynamics of events and outcomes, we selected only three model outputs to validate: (1) proportion of population that migrates to Thailand, (2) proportion of migrations that used irregular pathways; and (3) the range of precarity scores across all migration pathways. Table 31 summarises the comparisons between the empirical trends and simulated observations using the baseline model scenario. Overall, we found the patterns in system-level trends for the rate of migration, use of irregular channels, and precarity range to be consistent with the multiple empirical sources cited in Table 31.

Table 31. System-level pattern validation

1. Percentage of migrants in the population

Empirical trend:

- **Sussex Centre for Migration Research:** 19-36% of Myanmar households had at least one current migrant, 3-10% had at least one recently returned migrant, and 26% of all migrations were international (81)
- **International Organisation for Migration:** 10% of Myanmar's population migrate internationally each year (275)
- **Myanmar Living Conditions survey:** 7.5% of Myanmar households receive remittances from a family member living abroad (260)

Summary: Approximately, 7-10% of the population migrates internationally annually, predominantly to Thailand.

Simulation observation: On average, across the baseline runs (n=50), ~21% of migrants completed 1+ migration(s) during a run. This total is close to a conservative estimate of the empirical data (~7%) multiplied over 5 years. The simulation observation is lower, which reasonably accounts for migrants that go to other less popular international destinations of migrants that migrate multiple times contributing to multiple years' total migrants.

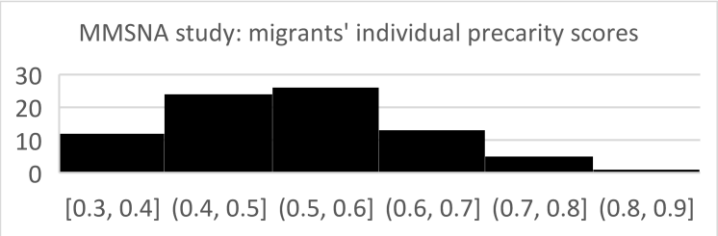
2. Proportion of 'regular' versus 'irregular' migrations

Empirical trend: International Labour Organisation: ~90% of migrations are through irregular channels in the Myanmar-Thailand corridor (82)

Simulation observation: On average, across the baseline runs (n=50), ~80% of migrants used irregular pathways. This is slightly less than the empirical findings, but as Yangon is one of the four 'origin' sub-areas, which is a more active hub for recruitment into regular pathways, we have decided not to change the calibrated recruiter behaviour to reduce this figure.

3. Range of migrant precarity scores

Empirical trend MMSNA study: From some of the event and outcome indicators that were not used to inform the study, we were able to calculate a similar precarity score to the one calculated in the ABM using the indicators for: legal status, livelihood pressure, family support, and knowledge of migration/destination (215). Most of the sample's precarity scores were between 3-6. See histogram below.



Simulation observation: On average, across the baseline runs (n=50), migrants' precarity scores were between 0.3-0.5 for most of the model runs.

Sensitivity analysis

Sensitivity analysis (SA) has been described as, "the evaluation of the influence of variable model inputs on the variability of a specific model outcome" to detect the strongest influences on the model outcomes to better understand causality (276).

It was not feasible to evaluate the sensitivity of the model outputs to changes in every parameter or all the possible interactions *between* parameters. Our initial efforts to evaluate the uncertainty of the model focused on the variability and possible interactions of two key model elements – migrant agent *preferences* and intermediary-intermediary agent *links*. These two model attributes were chosen because of their central role in determining the simulated options and decisions in the migration process, as well as their applied relevance for 'fair recruitment' intervention theories of change.

We conducted a 'two-at-a-time' approach to change these model elements, which is not as limiting as the 'one-at-a-time' (OAT) method, but not as complex or cumbersome as testing all combination of model parameters simultaneously. Table 32 summarises the three possible values assigned to each of the two factors and the nine possible combinations (labelled SA1-SA9) we tested (Appendix 7.19) for more detail.

We executed 10 runs for each of the nine combinations of *migrant preferences* and *intermediary-intermediary links*. For each run, we exported *accepted offers* and the *pathway precarity scores* and averaged across the probabilistic runs for each combination before comparing these averages. We observed that in SA- 2, 5, and 8 the total accepted offers from Thai Document Brokers drops dramatically in a similar pattern (Figure 37-A). These were the three SA setups that all included a *decreased* frequency of intermediary links, which could explain the notable decrease in Thai Document Broker offers that might be reliant on links to Employers. The trends in other accepted offers (i.e., from other agents) appeared predominantly unaffected by the two-factor changes. This highlights an important gap in evidence on how intermediaries link with one another,

which could have been beyond the knowledge of the migrants we interviewed.

When identifying changes in pathway precarity scores, we focused on the trends in the first 3 years of the graph as most migrants return home in the first 3-years of their migration (82). The precarity scores were relatively stable across all the SA simulations, except that the average family pathway precarity score in SA-9 was consistently lower than in other SA simulations (Figure 37-B). In this simulation, we used SA1 as a comparator with SA9. The two-factor combination was set so more migrants had preferences related to the destination or employment that they wanted (as opposed to a range of preferences) and any empirically feasible intermediary-to-intermediary links were set to a higher density, see Table 32. It is possible that this change in family pathway precarity highlights an interaction between increased offer options (due to more linked agents, which provides access to more combinations of offers) and preferences specific to destination or work, leading to a decreased precarity in informal family pathways, for example, due to the establishment of migration networks to similar locations, which increases social support at destination. This suggests we should investigate the interaction of migration preferences and options when determining trends in the use and outcomes of specific pathways. Appendix 8.4 presents the output graphs for all nine two-factor combinations included in the SA.

Table 32. Sensitivity analysis – two-at-a-time combinations

Model element – Baseline	Value 1	Value 2
1. Migrant preferences: Empirically informed distribution of all migrant preference options (81).	Equal distribution (25%) of the four preferences related to the migration *process* choices (intermediary, family, fees, legal) and no assignment of migration *destination* preferences.	Equal distribution (20%) of preferences related to the migration *destination* circumstances (social, work, sector, wages, proximity) and no assignment of migration *process* preferences.
2. Intermediary links: Empirically informed likelihood of links between intermediary-intermediary link combinations (215).	Decreased likelihood of links between intermediary-intermediary link combinations (only for the 'possible' links included in the Baseline scenario).	Increased likelihood of links between intermediary-intermediary link combinations (only for the 'possible' links included in the Baseline scenario).

		1. Migrant preferences	2. Intermediary links
All Possible Combinations	SA1	Baseline	Baseline
	SA2	Baseline	Value 1
	SA3	Baseline	Value 2
	SA4	Value 1	Baseline
	SA5	Value 1	Value 1
	SA6	Value 1	Value 2
	SA7	Value 2	Baseline
	SA8	Value 2	Value 1
	SA9	Value 2	Value 2

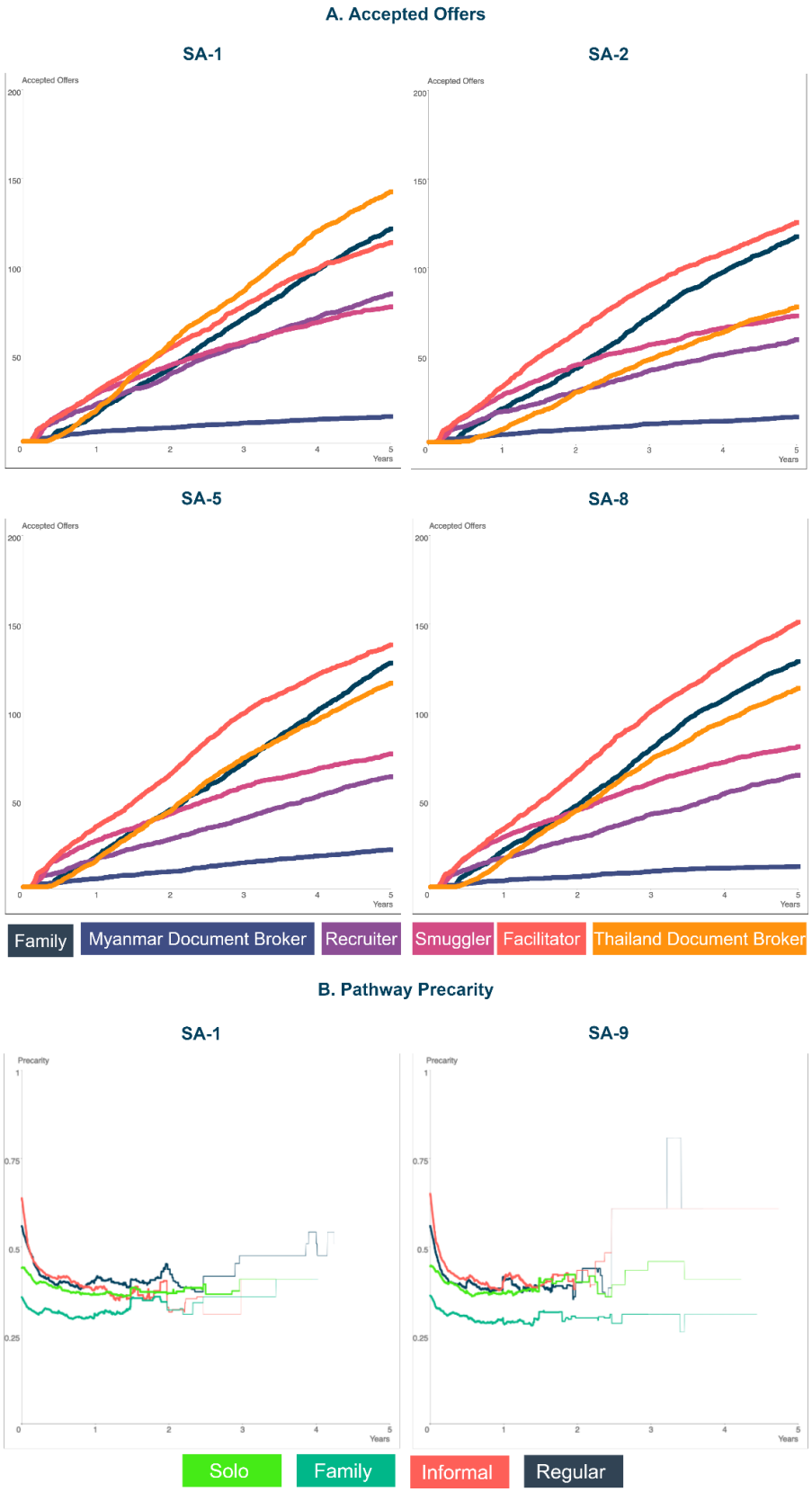


Figure 37. Sensitivity Analysis – two-factor changes

Model limitations

There is a range of different limitations to this work, which we consider to be opportunities for future work. First, it was not within the scope of this work to use any formal methods of verification, such as model replication or multiple updating techniques (277). These formal methods of verification can be used to interrogate models to identify underlying artefacts driving the emergent properties, instead of the explicit mechanisms being modelled. Modellers are increasingly attempting to reproduce one model using a different modelling method to both verify and validate the original model (277, 278). These formal methods are outside the scope of this work but would be valid methods for future evaluation of this model. Instead of using 'formal' tests of evaluation, we prioritised attempting new methods of qualitative verification and evaluation more suitable to the data available with the aim of contributing a new example of micro-level saturation tests for the model rules and pattern validation in lieu of large scale longitudinal quantitative datasets. The validation of this model is arguably weak at present, in part due to the scarcity of available data, however, this work contributes to a growing field of innovative methodological work on model calibration and validation, for example using the Pattern Oriented Method (POM) (279). Second, we have not conducted tests of structural uncertainty as the various stages of evaluation were extensive for this first iteration and write up. The parameter uncertainty we did conduct was limited to just two factors because of what was feasible within the scope of this work. Experts of ABM modelling advocate that sensitivity analysis (SA) is key to establishing model credibility and that ideally modellers should use mixed-methods approaches that take into account parameter interaction and different levels of uncertainty (276). However, these authors also acknowledge there is not a 'one size fits all' approach to SA approaches. Finally, for some of the specific rules and parameters there was still a scarcity of empirical data to inform the rules (e.g., which is more influential – a positive encouragement to migrate or a warning not to migrate?) This data scarcity on some of the

population trends and dynamics of outcomes also limited the extent of the system-level (or 'pattern') validation we could conduct. Finally, due to Covid-19 and political instability in Myanmar, we had to delay the stakeholder validation fieldwork we still intend to complete with relevant key informants in Myanmar and Thailand.

Discussion

The MyTh MaP-IN model utilises a rich mixed-methods dataset to inform the social and dynamic processes in the multi-level labour migration system in the Myanmar-Thailand corridor. We employed a participatory, migrant-led approach to conceptualise the actors, decision frameworks, and processes that shape migration pathways and outcomes. The long-term aim of this work is to use similar methods and iterations of this model for intervention design, testing, and evaluation. However, at this early developmental stage, our initial aim was to use the empirical social network data we collected to produce a descriptive model. A descriptive model can be used as a starting place to make sense of dynamic and complex phenomena that cannot be adequately captured in natural language or conceptual diagrams that are more comprehensible to a wider-audience (256). In that vein, MyTh MaP-IN serves as a timely touchstone for debate on the relationship between migration pathways and risk, as well as a 'tool for thinking' to foster more transparent discourse on current anti-trafficking programmatic assumptions.

Recent approaches to combat human trafficking have adopted an overarching theory of change: to prevent human trafficking we must make migration safer. However, the scarcity of evidence on what constitutes 'safe migration' limits the development of drilled-down theories of change to inform policy and programs. For example, the 'fair recruitment' model, which is the latest offshoot of safe migration approaches, has inherited the same untested intervention assumptions as the pre-migration trainings and awareness campaigns that have become synonymous with safe migration interventions (14, 280). In brief, these interventions theorise that regular or legally documented migration equates to a decrease in migrant labour exploitation. Yet, subject experts on migration and human trafficking are increasingly contesting this notion on numerous grounds. First, safe migration interventions often put the onus on migrants to practice self-protection with very little change to the ecosystem of complex challenges they are navigating (14, 280, 281). Second, there is emerging evidence that

challenges the assumption that regular migration *is* actually safer than irregular migration, most of which has been conducted in the Greater Mekong region (82, 249). Finally, as Sverre Molland contends from his work in the Cambodia-Thailand corridor, "legality does not 'dry out' dubious recruitment practices as they are taking place within the very same intimate networks that are supposed to constitute 'safe migration'"(281).

The MyTh MaP-IN results concur with the mounting objections to the conflation of "safe, orderly, and regular migration" by highlighting the various levels of hyper-precarity that cut across *all* migration pathways in the Myanmar-Thailand corridor. Furthermore, where there were distinctions between different pathway precarity levels, in this context, 'irregular' family-mediated migration was less precarious than migrating through regular formal channels using licensed recruiters. While legal recruitment practices can and should be improved in all contexts, these findings challenge whether legal or licensed recruitment in its current state should be the blanket recommendation for all migrants in all corridors because our findings suggest that many migrants are navigating irregular pathways in ways that avoid specific precarities present in the current documented pathways.

In addition to implications about which pathways might be more or less precarious, what also emerged from this empirically-based simulation was a greater understanding of the changing dynamics of pathway-specific precarity in transit to and in Thailand. The findings challenge the idea that risk is static and that, for example, being a regular or irregular migrant likens to a constant state of protection or risk. The finding that migration and employment decision-making (and precarity) often continue after an individual secures a job at destination as migrants change jobs, their legal status alters, further suggests that programming and policy-making must adopt a wider lens to include strategies to address workers' needs at destination. This model indicates that precarity can change over time and demonstrates the variability in precarity levels. Precarity is not simply 'livelihood uncertainty' experienced equally by all low-wage migrant

workers, but is a multidimensional, dynamic, and individualised experience of labour migration, or as Lewis explains it "[hyper-precarity] is a feature of broader life". This shift from static risk factors and simple dichotomies leads us to consider at which timepoints and within which pathways do migrants face windows of hyper-precarity or situational vulnerability that might leave them exposed to a range of abuses, adversities, or untenable choices. Moreover, the model also suggests that migrants' decisions are set within a system of likely job precarity, which sets the context for all individual and policy decision-making. While familiarity with a migration system can help us deduce reasonable assumptions about which indicators contribute to precarity in different pathways (e.g., higher debt in regular pathways, no documents in irregular pathways, etc.), we cannot always predict how migrants' preferences, decision-making, and social contexts shape their pathway choices, informed trade-offs, and subsequent experiences of precarity.

This work highlights the natural next step of inquiry to better equip this model for explanation and prediction by suggesting the next questions for future research and modelling: How and to what extent do migrants engage in critical comparisons of their options and preferences for migration? What are the constraints or limitations to these cognitive deliberations? How do migrants navigate the trade-offs or 'lesser evils' in migration decision-making across all stages of migration? In short, how do migrants perceive and navigate their own individual exposures to precarity in an already precarious system.

These questions are critical to ensuring that the next wave of safe migration interventions do not adopt a narrow perspective that fails to consider the lived-experiences of migrants or misunderstands the nature of the context in which migration decisions are made—or worse, accepts unproven assumptions that exacerbate risks for the many migrants that still choose to migrate through irregular channels. Based on this descriptive exploratory work, we posit that any research or intervention that treats migration

pathways as causal mechanisms for labour exploitation needs to recognise the importance of *hyper-precarity* versus *legality* as the most influential aspect related to 'safe migration'. For example, current 'fair recruitment' initiatives make the implicit assumption that irregular migration comprises the greatest risk and legality holds the greatest promise, without necessarily accounting for the wide-spread context of hyper-precarity of migrant workers. That is, regular migration is not a precarity-free pathway and, in fact, in the Myanmar-Thailand corridor many of the current trends in regular migration indicate that this pathway might put migrants in greater positions of vulnerability due to the high costs and subsequent livelihood pressures, narrow options and therefore limited control over their final destination or employment situation, in addition to strict documentation requirements that leave migrants vulnerable to losing documents after arriving (91). In this sense, the simulation results indicate that migration pathway choices are not clear-cut options of safe versus unsafe, but a complex array of options with varying trade-offs.

Methodological contributions

While this work is primarily empirical, this model contributes to advancing the field of computational social science by having applied a novel mixed-methods and interdisciplinary approach to model development and evaluation. The ABM community is grappling with how to foster more interdisciplinary work that harnesses both technical and subject expertise to address real-world problems using complex systems thinking. Decision-makers working on pressing complex problems under various resource constraints can benefit from tools that are grounded in empirical evidence and sufficiently capture the system's dynamics. All intervention development and policy-making consist of some elements of 'prediction', and ABM can offer support in making those predictions and testing underlying assumptions. This model pushes the field of migration ABMs beyond simulations of basic demographic and economic trends to consider to what extent we might be able to simulate the heterogeneity of individual

networks, planning, and pathways with enough reasonable likeness to warrant complex systems modelling as a tool for intervention research. It can help the migration intervention field progress beyond 'logical assumptions'. This ABM also provides a 'proof of concept' for other interdisciplinary and applied research teams working on interventions for complex problems and/or in complex settings (13). For example, it provides evidence how a non-technical social scientist can assume the role of modeller if there are clear strategies for communicating the model specification to the programmer to ensure accurate translation from conceptual to computational. The success we had in our approach indicates the ways a programmer and modeller can work in unison across all stages of model planning, design, build, evaluation, and analysis. This collaborative approach challenges many of the norms that have historically divided the work of social scientists and computer scientists and, perhaps, slowed the advancement of interdisciplinary approaches to using ABM methods amongst social scientists working on complex problems. Many social scientists and practitioners working on the world's most pressing challenges think in complex systems conceptual models that could be feasibly translated into computational models for theory development and testing. However, the examples of these interdisciplinary efforts are still rare. There has been a recent deluge of methodological commentaries making the case for complex systems methods and even suggesting roadmaps for the way forward (13, 100, 104, 142, 155), but in most cases, there are few applied examples of advances to complex systems research design across social science disciplines. This work attests to both the potential challenges and successes in this area.

Finally, our innovative use of empirical methods, especially qualitative methods, to inform and validate the model design (i.e., mixed methods social network analysis, micro-level qualitative rule validation) present promising ways forward for ABM building in data-scarce research fields. To our knowledge, this is one of the first examples of an empirical mixed-

methods egocentric network analysis study being designed to inform an ABM.

Conclusions

The conflation between and assumptions about safety and legality have characterised most recent safe migration approaches. There is a worrying resistance among stakeholders to consider that in some contexts, particularly neighbouring border migration, migrants might in fact already be aware of, weighing, and navigating risks and determining that irregular migration is not just the most frequented pathway by their kin and social circles, but that it is indeed safer in their given context—which indeed corresponds to our findings. The blanket agenda to promote legal migration and formal recruitment without understanding the causal mechanisms of these different pathways in different contexts is a naïve, potentially reckless, way forward that could disrupt existing channels of migration that are keeping migrants safer at destination. Many of the current simplified assumptions driving safe migration interventions can be more transparently addressed using ABM and other complex systems methods.

This final chapter synthesises the conceptual, empirical, and methodological contributions of this thesis and builds on the discussions that have been presented in the four papers.

First, this thesis contributes new conceptual understanding of low-wage labour migration as a complex system of social and intermediary actors operating at micro- and meso-levels across migration stages and geographies. This work includes developing an original multi-level migration theoretical framework (Figure 4) and a complex low-wage labour migration conceptual framework (Figure 6), which adopt a complex systems approach to explore causal pathways. Both frameworks can be adapted and extended for future migration research. Many renowned migration scholars, such as Massey, Arango, Brettell and Hollifield, have argued that interdisciplinary approaches and integrated theory are essential to advancing migration research, which cannot be sufficiently addressed by any single theory (105–107, 282). Others, like Hein de Haas, contend that migration studies at-wide are under-theorised and that, "Big-picture migration theory-making has been largely abandoned, particularly since the rise of 'postmodern' approaches, which have stressed the role of agency and the unique character of migration experiences." (283, p. 4) Bakewell's revised migration system theory and Hein de Haas's aspirations-capabilities framework offer two examples of contemporary migration theories that consider both *structure* and *agency* by cutting across empirical levels of analysis, but these are outliers, as most migration research utilises siloed theories of migration, if any (107, 115). The conceptual development in this thesis contributes to 'big-picture' migration theory by taking a systems approach to framing migration processes embedded in social and structural environments but also retains the 'postmodern' emphasis on the role of individual agency in executing motivation- and preference-driven decision-making within that system. Structure and agency are both essential when studying an emergent phenomenon such as migration, because as social simulation expert Nigel Gilbert explains, "Emergence occurs when interactions among objects at one

level give rise to different types of objects at another level . . . it requires new categories to describe it which are not required to describe the behaviours of the underlying components." (284, p. 11) Low-wage labour migration consists of series of decisions, behaviours, and interactions that give rise to patterns of migration pathways. For example, as migrants find 'success' in irregular pathways, their example produces feedback that influences others' migration decisions. This interplay between agency, feedback, and macro-structures, be they institutional or social, requires the use of systems approaches to situate individual expressions of agency as one component of a greater whole. The conceptual work contributed by this thesis fluidly crosses the agency/structure divide to capture as much of the lived-complexity of migrants' experiences within the system of migration. Acknowledging the role of both structure and agency in this conceptual work is also in line with the tenets of critical realism, the philosophy that informed this thesis.

Second, the empirical contributions of this thesis provide timely insights on migration intermediaries, networks, and pathways and how they shape dynamic experiences of precarity. This empirical work includes evidence that challenges the villainisation of intermediary types or irregular pathways as synonymous with risk, and likewise that licensed actors or regular pathways are synonymous with safety. While these findings are specific to the Myanmar-Thailand context, they are likely to be relevant to many other migration corridors between countries that share a border. This thesis set out to explore context-specific causal mechanisms that contribute to Myanmar migrant labour exploitation in Thailand. While inductively exploring migration narratives for descriptions of causal pathways, what emerged was a nuanced picture of individual and situational experiences of both work and social precarity that presented across all migration pathways, including narratives where migrants followed the legal and recommended recruitment processes. Safe migration policy and practice often make blanket recommendations for migrants to use legal channels to avoid dangers in irregular routes. However, these recommendations that aim to

prevent the precarity of being undocumented do not acknowledge the range of financial, legal, and social exposures that put migrants in situations of precarity in their work *and* their general living conditions, including, for example, isolation from social support, compounding and transnational livelihood pressures, and even distance from the border. Thus, it became imperative to the research aim to not look at the direct cause of severe exploitation but to first consider the multi-dimensional experiences of 'hyper-precarity' that are on the continuum of migrants' outcomes and exposures at destination (26).

Third, this thesis advances the use of complex systems modelling for safe migration intervention research by going beyond a conceptual framing of complexity and endeavouring to simulate or "grow" the system from its micro-decisions and behaviours, what Epstein describes as the future of explanatory research (143). These methods provided a way to organise, explore, and comprehend complex narratives of causality where other methods struggle to move beyond qualitative or aggregate descriptions of associations. Advancing complex systems methods to research a data-scarce topic such as migration mediation required innovative approaches, new tools, and participatory methods to collect, analyse, integrate, and visualise datasets that can capture the complexity of the system and mechanisms.

In this chapter, **Sections 5.1 - 5.3** discuss this thesis' foremost themes pertaining to migration mediation, decision-making, and pathways, which all have direct implications for safe migration practice and policy. **Section 5.4** discusses the advantages in applying complex systems methods to address migration, which has implications for future safe migration intervention research. **Section 5.5** discusses some of the limitations of the interpretations of these thesis findings. **Section 5.6** concludes this thesis and proposes the next steps for this research area.

5.1 Myanmar-Thailand mediators: good or bad actors?

In the Myanmar-Thailand corridor, different types of intermediaries tend to contribute in specific ways (e.g., *facilitators* make plans, *brokers* secure passports, *smugglers* execute transport). Among the most important findings was that there was not evidence that any single intermediary group was a consistently 'risky' or 'safe' choice. Migrants said 'there are good ones and bad ones' when describing facilitators, brokers, recruiters, and smugglers. Some added that they 'wished for a good one' indicating a degree of unavoidable uncertainty. Individuals that provided free assistance and were often social contacts (i.e., 'helpers') were the only intermediary group that were described consistently as selfless and trustworthy. Despite general uncertainty, many migrants said their migration was only achievable with the help of an intermediary.

These findings challenge or at least juxtapose certain stereotypes of unlicensed intermediaries, usually 'brokers' or 'smugglers', as all bad, and conversely, licensed recruiters as the preferred choice. For example, empirical research on migration industry practices in Thailand posits that "it is widely recognised that brokers target vulnerable populations to accept work in exploitative conditions" (285, p. 4). Another study on migrant vulnerability claimed that "if verified information is not readily available through obvious, official channels, then local agents, intermediaries and employers will be able to leverage their superior control of resources to exploit migrant workers with relatively low cost and risk." (47, p. 10) Many safe migration interventions portray informal intermediaries as guaranteed risks, which contradicts some migrants' positive experiences with these actors. For example, another study in the Myanmar context reported that undocumented migrants used informal intermediaries at destination to successfully acquire new documents or find new jobs (63). Other research reports that typically informal intermediaries are often embedded within Myanmar migrants' social networks (286). These are the types of assumptions and their contradictions that need to be re-considered by those continuing to assert common platitudes that safe equals official.

These less damning depictions resonate with recent studies exploring smuggling practices, which argue that "the predator-victim binary used to designate the smuggler-migrant relationship [is] a narrow portrayal of complex cooperation and mutually beneficial interactions . . . both smuggling facilitators and migrants are often members of the same social networks." (248, p. 13) alternatively, just as informal mediators are not exclusively predatory, there is growing evidence that *licensed* recruiters, often championed as the safe choice, still deceive or exploit migrants in some instances (80, 91). These varied narratives depict a much more nuanced exchange between migrants and intermediaries, sometimes 'good' and sometimes 'bad'.

The deconstructing of the predator/protector binary challenges programmatic assumptions that steer migrants exclusively toward licensed recruiters with the misleading assurance that intermediary 'type' alone is a determinant of safety. While there is emerging evidence that links unfair recruitment to exploitative outcomes (68), safe migration initiatives have made a chasm-jump from evidence of some unscrupulous actors to weakly supported claims that all unlicensed intermediaries are dangerous. This mischaracterisation of intermediaries does not reflect migrants' lived-experiences of informal mediation.

Recommendations: Safe migration and fair recruitment interventions should avoid simplistic rhetoric that villainises or esteems any single type of intermediary. Our findings show that, at least for Myanmar-Thailand low wage migration corridor, these characterisations are more nuanced. Migrants are likely to perceive the disconnect between these broad stroke perspectives and their lived experiences of what one migrant described as 'our system'. Second, safe migration initiatives should aim to understand better why migrants put trust or reliance on certain actors and attempt to integrate those actors and existing chains of support into the formal processes, which may require incentivising intermediaries and migrants alike.

5.2. Migration decision-making strategies: maximising or satisficing?

Both preferences and restrictions influence Myanmar migrants' decisions about how to migrate and who to rely on for help. Many migrants leave home with some level of uncertainty (e.g., undetermined job, vague contract, unknown transit route), but with 'enough' of a plan to meet their threshold for leaving home.

Migration decision-making often occurs within situations of 'bounded rationality', for example, situations where migrants do not know or cannot process all their options, or what Brunarska describes as the "good enough" choice (14, 287). In these cases, migrants tend to rely on family or friends for information or advice to shortcut decision-making processes (286). This corresponds to emerging evidence that migrants do not always practice fully informed, 'risk-averse' decision-making, but instead mitigate risks through their social capital at destination (60, 117). Other research in Myanmar reports that migrants try to choose intermediary help based on what they know about their reputation through their social networks (286) or based on what level of agency an intermediary can help migrants exercise (59). In other words, are they vetted by people I trust, or can they help me achieve my plan?

These findings call into question some of the theories of change in recent pre-migration and awareness-raising campaigns that aim to influence migrants' decision-making (280). The implicit assumption of these programmes is that if migrants are informed about safe migration strategies, typically legal migration strategies, that migrants will optimise their planning strategies to meet those prescribed safe migration benchmarks. However, migrants may have their own aims or preferences that supersede or conflict with those advised strategies, or they may be more prone to satisficing strategies (i.e., take the first option that 'fits the bill'). Further, there is an assumption that migrants choose irregular pathways because they are unaware of the risks, but in many cases, migrants are aware of the risks (58)

and indicate that trust in family or a specific intermediary is the main motivator for their choice of an irregular pathway.

Recommendations: Safe migration and fair recruitment interventions should embed themselves within existing social and migration networks that prospective migrants rely on to make decisions and consider how to best support migrant-led decision-making in its current context. These interventions should take a more grounded approach to integrating migrants' short- and long-term goals into the scope of regular migration channels. Myanmar-Thailand regular migration channels (or 'MOU migration') typically force migrants to forego certain benefits of irregular migration, such as efficiency, low costs, control over destination/employer decision, flexibility to change situation after arrival, in exchange for the promise of certain protections of being a documented worker. However, these regular pathways may not satisfy migrants' preferences or may not present as options at the timely moment that migrants feel ready to choose the first 'satisfactory' offer to migrate. Where feasible, 'safe migration' should be as satisfactory to migrants' aims as it is to government's aim for orderly migration if it is going to be an attractive choice for migrants.

5.3 Unsafe migration: dichotomous risk factors or complex causality?

Myanmar labour migrants in Thailand are exposed to multi-dimensional levels of precarity, that include, for example, workplace, livelihood, immigration, and social factors. These experiences often amount to situations of *hyper*-precarity, which leave migrants in compounded states of vulnerability within already precarious systems. These experiences of precarity are not static but prone to fluctuations due to changes at their destination, such as, losing or gaining documents, switching jobs, or changing social network compositions. Moreover, these multidimensional experiences of precarity cut across all migration pathways in the Myanmar-Thailand corridor, and were highest in the regular pathways due to high costs and a tendency for migrants to lose their regular status.

Evaluations of the effectiveness of the Myanmar-Thailand MOU procedures (i.e., the only official legal labour migration channel) report that the process is too time-consuming, costly, and complex for migrants, which is why the majority still choose irregular routes (80, 91). Often it is assumed that migrants overlook the risks or irregularity to reap the rewards of migration, but recent narratives shared by migrants imply that they are weighing the different investments and risks for different pathways and, at this stage, irregular migration is the more attractive and less burdensome option (80, 91). Other research conducted by the ILO reported that migrants who relied on verbal agreements for their jobs were more likely to get the agreed job than those with written contracts (82). Using this same ILO data, Maryann Bylander compared multiple outcomes among regular and irregular migrants in the ASEAN region and concludes that regular migrants face substantively higher costs and poorer outcomes than irregular migrants (249).

Programmatic assumptions of what are ‘unsafe’ versus ‘safe’ migration pathways remain highly speculative and laden with polarising debates on topics, such as irregular versus regular migration, licensed versus unlicensed recruiters, and fair versus unfair recruitment. Much of the rhetoric relies on

framing risk as dichotomous factors instead of more appropriately as complex and dynamic sets of experiences that produce states of precarity and continuums of outcomes. There are a range of international policies and UN guidelines that address the rights of irregular migrants (288), yet the majority of safe migration intervention messages solely emphasise the benefits of *legal* migration versus informing migrants of their rights if they choose to go irregularly. Scholars studying the evolution of migration industries argue that a more nuanced understanding of irregular migration processes has important implications for policy deliberations (288, p. 132). A simplified approach to establishing a 'one-size fits all' fair recruitment model discourages what should be a broader exploration of risk and safety in labour recruitment channels. As a result, interventions often fail to address how different migrants navigate the varied forms of unplanned or informally organised migration pathways.

Recommendations: A true global model of fair recruitment needs to include interventions that address irregular migration pathways. Current tripartite safer migration initiatives are often bounded by national and international laws to govern orderly and regular migration, which then skews how these interventions define 'safe migration' and limits the ways they can prioritise migrants' wellbeing and preferences. The current fair recruitment model is fair recruitment for *legal migration* and should be branded as such until it can navigate how to offer protections in irregular pathways. Further, these initiatives should carefully identify and weigh the consequential, potentially unintentional, harm that legal-centric interventions could have on many migrants using informal channels, often with relatively informed reasons for doing so.

5.4 Complex systems methods for safe migration intervention research

For decades, migration researchers have stressed that human trafficking and all forms of migrant labour exploitation are 'complex problems' (7). International stakeholders, such as the IOM, acknowledge that there are different levels of interacting risk and protective factors, and that vulnerability results from "an overall preponderance of risk factors, coupled with inadequate protective factors." (289) Yet, the analytical strategies informing safe migration policy and practice have mostly failed to incorporate these multi-level theories. Across the field of migration research, there is a paucity of intervention evidence to inform programmatic theories of change for preventing labour exploitation across different contexts (252). Programmatic assumptions do not account for the heterogeneity of actors, actions, interactions, and dynamics that contribute to the complex causality of labour exploitation.

Most 'modern slavery' and migrant health research has applied traditional epidemiological methods to explore associations between exposures and outcomes. These reductionist statistical approaches measure health outcomes and associated risks, which is suitable for disease or injury prevalence but dangerously simplifies socially embedded, complex causality to linear one-dimensional and unidirectional cause and effects (290, 291). While some migration researchers are discovering the explanatory power of complex adaptive systems frameworks that emphasise the *relationships* connecting constituent components (134, 136, 190), to date, few migration researchers are proficient in computational social science or complex systems modelling, such as ABM. These tools have the potential to identify cost-effective safe migration interventions and alternative rigorous research designs to traditional experimental methods, such as randomised controlled trials (257), but they remain under-tested (292). This thesis concurs with other modellers that have attempted to simulate migration and concluded that there is a missing element of complexity in simulated migration decision-making processes (134). Scholars exploring the intersection of cognition and multi-agent systems have emphasised opportunities to

integrate cognitive modelling into social studies addressing complex behaviours that originate in individual perceptions (203).

Recommendations: Safe migration and anti-trafficking intervention research should adopt complex systems thinking *and* methods in research design. Ideally, researchers should utilise methods such as ABM that force transparency about programmatic assumptions and which can be used to test counterfactuals not easily tested in the real-world. Complex social simulations can only be as insightful as the data that inform them. Thus, it is essential that any complex system research design includes strategies for how to collect the types of multi-level data that can provide insights on the relational, temporal, and spatial characteristics of the system. Participatory mixed methods and social network approaches are aptly suited to capture the complex datasets needed to inform both the structures and processes embedded in an ABM. Future ABMs should look to include more specific decision-models across the migration stages, including for example, how migrants adapt to changes or obstacles during their migration or to system-level changes (e.g., border closures, new immigration policies) (134).

5.5 Limitations

Each paper addresses the limitations specific to the methods of that paper. This section discussed some of the limitations to the overall study design and more specifically limitations to how the results can be interpreted and used.

First, as acknowledged in the papers, the sampling limits the generalizability of these findings as they are not representative of all Myanmar migrants in Thailand. However, the diverse and mid-size sample (n=100), in terms of gender, age, geography, and work sectors presents a broad scope of experiences that are likely to resonate with many other migrants in the Myanmar-Thailand corridor and offer valuable insights for interventions. The findings are specific to this corridor in the years 2014-2019 and cannot be assumed to be generalizable to dissimilar migration corridors (e.g., corridors that do not share a border and have heavier reliance on recruitment and visa systems, such as Ethiopia to the Gulf States). Further, some of the immigration processes between Myanmar and Thailand, such as the types of documents available, are subject to changes, which may influence migrants' preferences or intermediaries' roles that are beyond the scope of this work. Moreover, the first analysis of the empirical data collected for this thesis offered an overview of the findings, but did not present results stratified by gender, age/generation and ethnic background of migrants. Future analysis of these data will focus on these aspects.

Furthermore, the interviews were conducted in Burmese, which limited the English-speaking researchers from engaging directly in the data collection and subjected the interviews to potential lost meanings or nuances in the translation processes. While I completed three courses in the Burmese language to provide basic conversation and report building, none of this training enabled me to speak directly to interviewees or read the transcripts in Burmese.

Lastly, as the ABM is a significant contribution of this work and a first attempt to use this method on this subject area, it is important to acknowledge that some of the model design relied on assumptions that have not yet been validated using empirical evidence (e.g., potential differences in the proportion of motivation changes from positive versus negative social influences). Most notably, the 'precarity score' used to formalise the outcome in the ABM has not yet been formally tested and validated as it was not within the scope of this thesis. The field currently lacks a carefully calibrated general measure of precarious work, and especially one that is specifically developed for mobile workers (293). This study undertook some of the basic steps in building a composite indicator (i.e. defining the purpose and scope, selecting a conceptual framework, and searching for candidate indicators) (294), but did not carry out formal analysis to weight indicators, test internal consistency, validity and reliability of results (295). However, all the indicators included in this score were informed by a strong body of theoretical and empirical work and verified as important indicators of relevance to the Myanmar-Thailand context using the empirical data from the MMSNA study.

5.6 Conclusion

This thesis fills a gap in our understanding of mediated migration in the Myanmar-Thailand corridor and how mediated pathways shape migrants' varied experiences of precarity. The aim of this study was to gain a greater understanding of the dynamics of labour migration to provide a clearer picture of the labour mediation systems that can lead to exploitation, which safer migration interventions work to disrupt. The long-term purpose of this work is to provide a tool with which to identify causal mechanisms of 'modern slavery' to guide and prioritise prevention strategies.

In addition to new empirical insights on the role of mediators, networks, and pathways, this thesis also contributes new frameworks and methods to use in anti-trafficking and safe migration intervention research. These methods offer more appropriate approaches to inform the kinds of multi-component

interventions that are better suited to prevent migrant labour exploitation in complex settings. Both the conceptual framework and empirical simulation provide a future bedrock from which other complex migration systems intervention research can build. In fact, the next steps of iterating and validating this work will be completed as part of a new ESRC-funded methods innovation project exploring new uses of complex systems methods for migration and violence research.

In the dawn of the 'complexity science' revolution, Grimm's words provide important warning for work such as this:

> "Scientists sometimes tend to rush to a new approach that promises to solve previously intractable problems, and then revert to familiar techniques as the unanticipated difficulties of the new approach are uncovered" (296, p. xi)

Achieving the empirically and theoretically informed ABM presented in this thesis was not without a range of unanticipated difficulties, but the possibility of new tools to comprehend and prevent the causes of migrant labour exploitation motivated this work to push beyond those challenges. The result was not just a model, but what David Byrne aptly describes as a "metaphor with which to tell the truth" (100, p. 43). The qualitative truth is that Myanmar migrants face a range of uncertainties, risks, and precarities in the hope of better futures and the systems they navigate can and should be made safer. This thesis takes hope that empirical research that listens and tracks the complexities of migrants' lived-experiences can and will make some difference.

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A.1 Contributions to migration and health scholarship

During my time as a doctoral student, I contributed to two pieces of research on the occupational health and wellbeing of migrant workers. While my own thesis did not focus directly on measuring health outcomes, these two pieces of work made critical contributions to the field of migrant health research. My involvement in these publications provided valuable background learning on labour migration outcomes relevant to exploring causal mechanisms and framing outcomes in labour migration systems.

A.1.1 UCL-Lancet Commission on Migration and Health

In the first year of my doctoral studies, I was a contributing author to *The Lancet-UCL Commission on Migration and Health* (8). Alongside my supervisor, Professor Cathy Zimmerman, I co-authored the sections of the report on labour migration and human trafficking. One of my contributions to this piece was a synthesis of studies reporting on migrant occupational health, particularly on any distinctions that could be made between migrant and native workers' occupational health. Table 33 is the main output of that synthesis that was included in the main body of the final publication of the commission.

Table 33. Low wage sectors & occupational hazards, The Lancet-UCL Commission on Migration and Health (8)

	Examples of occupational hazards and harm	Migrant health study findings
Sex work	Poor condom negotiation or use can cause sexually transmitted infections and unwanted pregnancy; sexual violence and confinement can cause anxiety disorders and depression	Migrant female sex workers in Benin, Ethiopia, and Kenya are at greater risk of HIV than non-migrant sex workers and higher risk of acute sexually transmitted infections in all settings
Construction	Work at heights can cause fatal falls and disabilities; heavy lifting can cause musculoskeletal problems; poor personal protective equipment can cause respiratory disease, dermatitis, and eye injury	In the USA, Latino construction workers were nearly twice (1·84, 95% CI 1·60–2·10) as likely to die from occupational injuries as their non-Latino counterparts
Manufacturing (eg, textiles)	Repeated bending and fixed postures can cause musculoskeletal damage and pain; sharp instruments can cause puncture wounds; dust particles can cause silicosis	In Malaysia, 64% of migrant workers had musculoskeletal pain caused or worsened by work compared with 28% of Malaysian non-migrant manufacturing workers
Commercial fishing	Environmental exposures (sun, cold, rain) can cause skin cancer, dehydration, frostbite; long hours and weeks with no break can cause exhaustion and pneumonia; unstable fishing vessels and inadequate life vests can cause drowning; fishing net and knife hazards can cause deep cuts and lost limbs	Survivors of trafficking working in the Thai fishing industry reported higher injury rates (47%) than non-trafficked fish industry workers (21%); 54% of trafficked fish industry workers experienced severe violence versus 10% of non-trafficked fish industry workers
Agriculture	Pesticide exposure can cause toxicity; environmental exposures (heat, cold, mosquitoes) can cause dehydration, kidney failure, headaches, and malaria; heavy lifting and bending can cause repetitive injury syndromes	In one greenhouse in Oman, 95% of workers were migrants; poor practices related to pesticide use resulted in numerous health problems, such as skin irritation (70%), headaches (39%), and vomiting (30%)
Domestic work	Physical, sexual, and verbal abuse, and social isolation can cause depression, anxiety, and suicide; extensive working hours and food deprivation can cause exhaustion; repeated lifting, bending, and reaching can cause musculoskeletal strain; chemical cleaning agents, cooking, ironing, and knives can cause skin damage and burns	A 2-year study in Kuwait found that hospital admission rates for domestic workers (93% from India, Philippines, and Sri Lanka) were 1·86 times higher than for Kuwaiti women (non-domestic worker control group); stress-related disorders were more common (49% *vs* 22%) in housemaids (of whom a majority are migrants) than Kuwaiti women
Mining and quarrying	Mercury extraction, lead exposure, and mineral dust can cause mercury poisoning (gold-mining), neurotoxic disorders, and pneumoconiosis; heavy lifting, falls, and falling rocks can cause fatalities, traumatic injuries, and disabilities; heavy equipment, long hours, and repetitive lifting can cause noise-induced hearing loss, long-term fatigue, and musculoskeletal injuries; remote locations can cause malaria and put individuals at risk of venomous snake bites	China's Ministry of Health reports that 87% of occupational disease is pneumoconiosis (black lung disease), with a mortality higher than 20%; pneumoconiosis is a chronic lung disease that often affects miners, sandblasters, and metal grinders, occupations undertaken primarily by internal migrant workers
Forestry	Environmental exposures (heat, cold, mosquitoes) can cause dehydration, malaria, and infection with parasites; falls, sharp tools, and machinery can cause fatalities, broken bones, and lacerations; repetitive motions and long hours can cause pain, strains, and long-term fatigue	A study of Burmese migrants found 87 (83%) of 105 rubber plantation workers had a suspected case of malaria in the past year; workers had poor access to care because of their working hours and poor transportation
Leather and tanning	Chemical exposure (ie, chromium, benzene dyes, formaldehyde) can cause respiratory illness, ocular damage, cancer, ulcers, toxicity, dermatological diseases (rashes), and chronic or allergic bronchitis pulmonary tuberculosis	Higher morbidity rates were found in tannery workers (40%) than the control group (20%) in northern India
Brick kilns	Unsanitary environments and air pollution can cause bronchitis, asthma, silicosis, and respiratory toxicity; very high heat can cause burns and fatalities; high rates of child labour resulting in developmental problems for those children	Migrant brick kiln workers in south India had higher prevalence of chest symptoms (9%) versus general population rates (5%) related to occupational hazards and poor health-care access

Table: Low wage labour sectors and associated occupational hazards among migrant workers (see appendix for full list of references)

A.1.1 Occupational health outcomes among international migrant workers: a systematic review and meta-analysis – Lancet 2019

In the second year of my doctoral studies, I was a contributing author to a systematic review and meta-analysis of the occupational health outcomes among international migrant workers. The aim of this review was to describe occupational hazards and health outcomes associated with different work sectors and to summarise the global prevalence of occupational morbidity in migrant workers. The purpose of this review was to promote policy that strengthens occupational safety and health as well as responsive health services for all migrant workers in receiving countries.

As a co-author, I contributed to the design of the study protocol, screened the articles for inclusion, and reviewed and contributed to the final draft of the paper, which was then published in *The Lancet Global Health*.

Hargreaves S, Rustage K, Nellums LB, McAlpine A, Pocock N, Devakumar D, et al. Occupational health outcomes among international migrant workers: a systematic review and meta-analysis. The Lancet Global Health. 2019; 7(7):e872–82. https://doi.org/10.1016/S2214-109X(19)30390-0

A.2 Conceptual framework development

The conceptual frameworks (CFs) for this thesis were developed during the study design and data collection phase and eventually consolidated to the final conceptual framework depicted in Chapter 2 – Figure 6 of this thesis. A.2.1 shows some of the early CFs developed in preparation for my Year-1 MPhil to PhD upgrading examination. A.2.2 shows some the CFs that had more explicit detail of the data to collect in the mixed methods interviews.

A.2.1 Conceptual frameworks submitted for Upgrade Examination (09/2018)

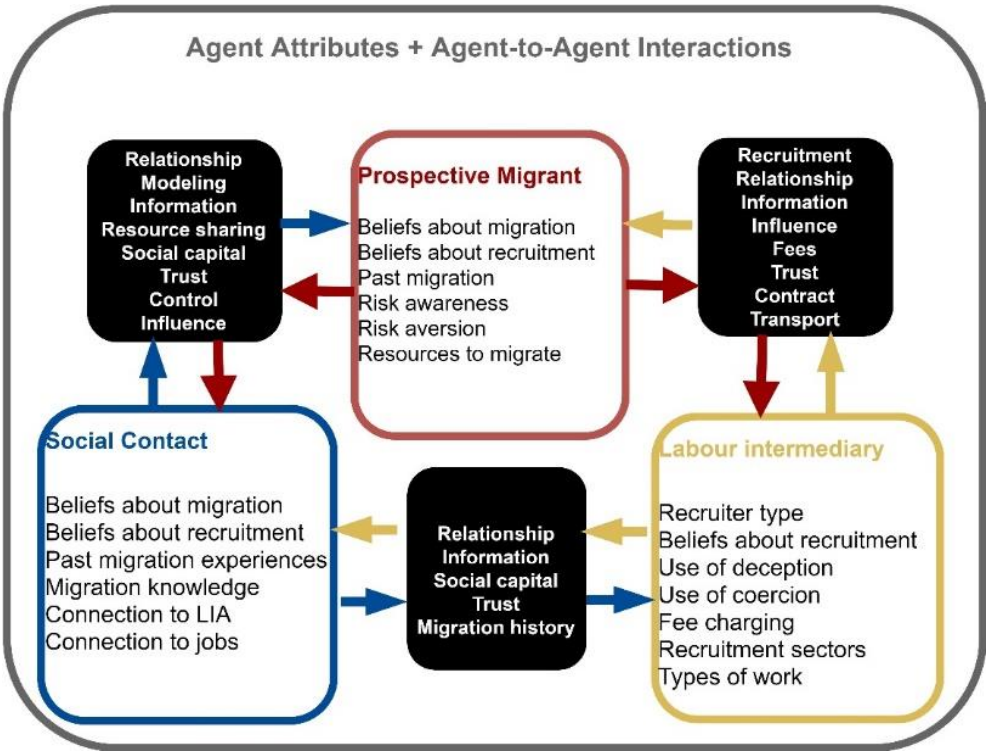


Figure 38. Upgrading report CF 1

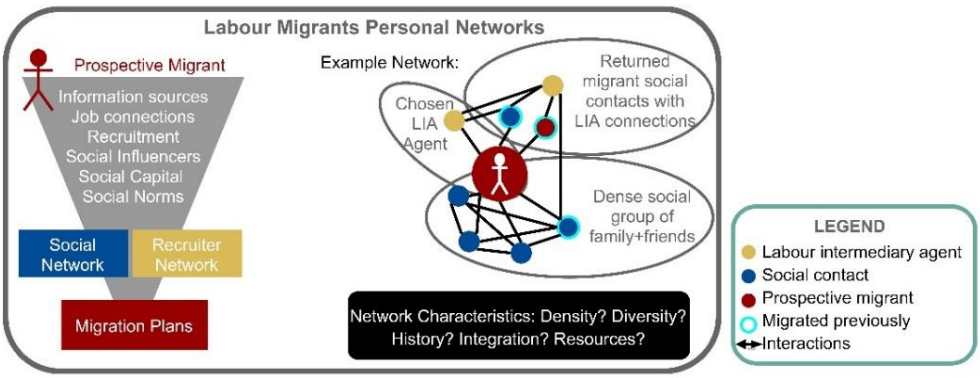


Figure 39. Upgrading report CF 2

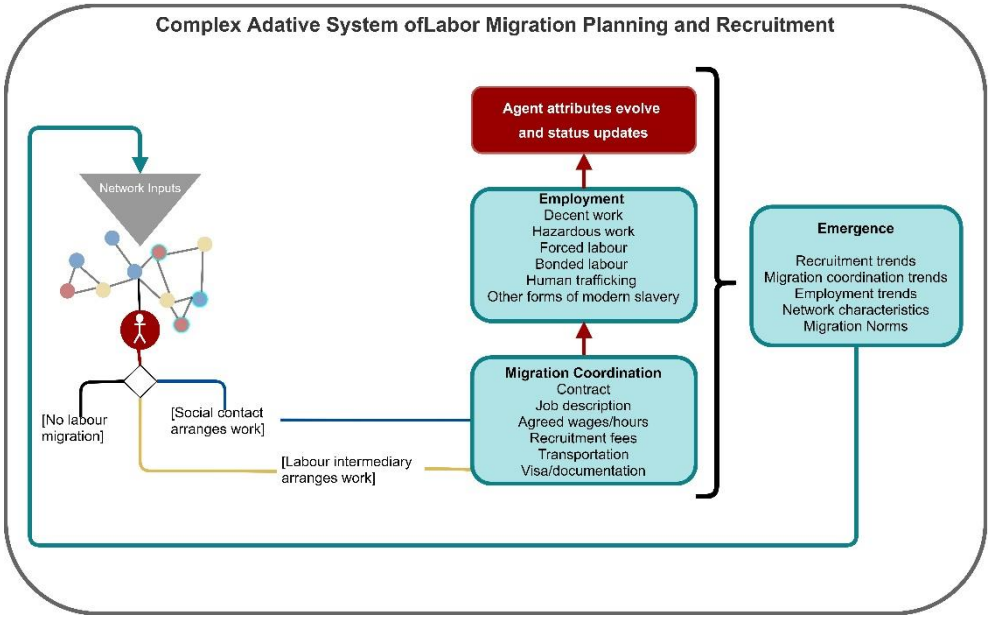


Figure 40. Upgrading report CF 3

A.2.2 Conceptual frameworks that guided data collection (01/2019)

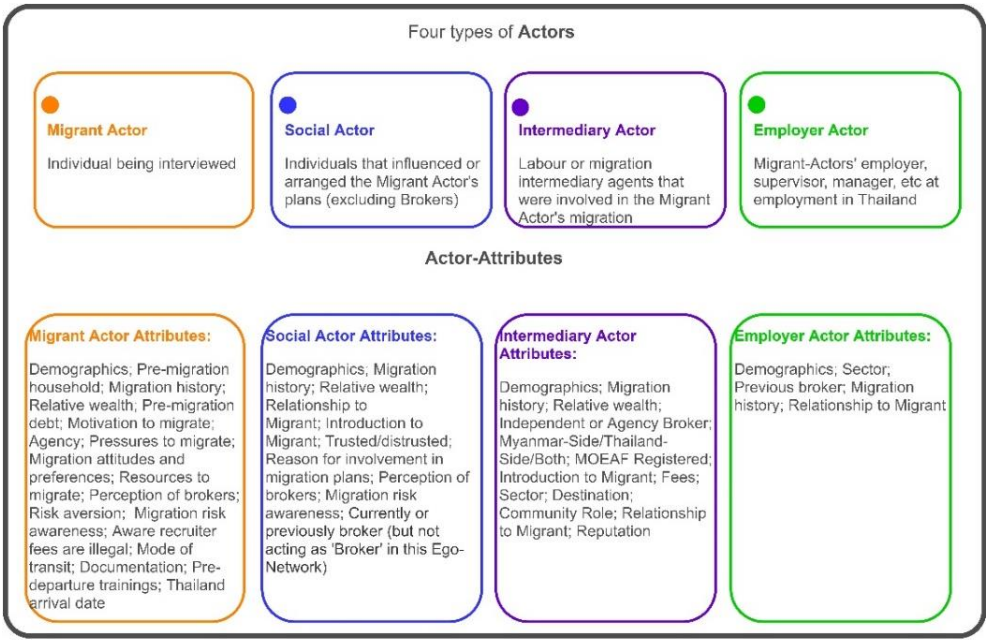


Figure 41. Data collection CF 1

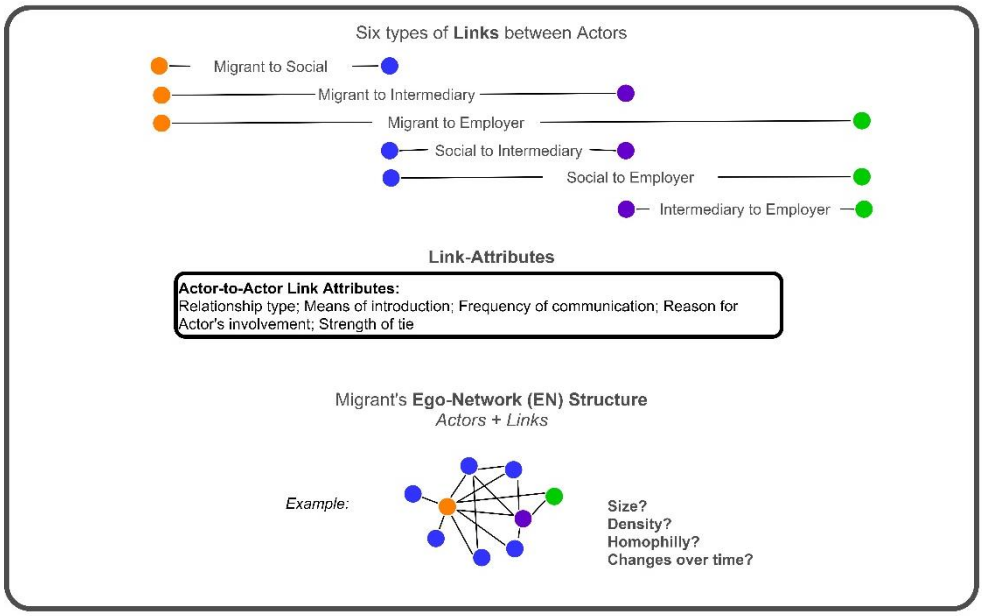


Figure 42. Data collection CF 2

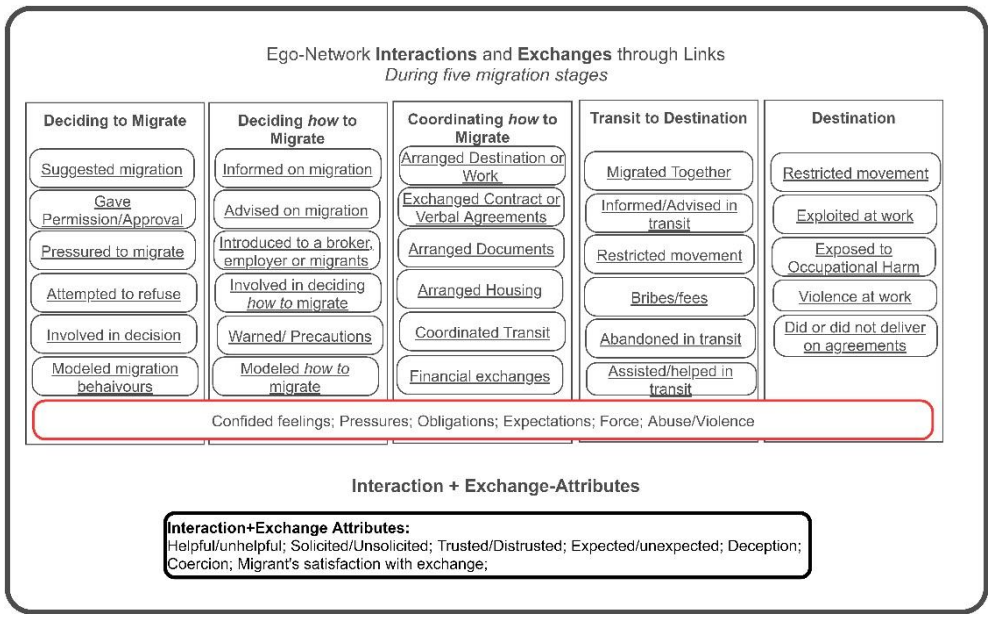


Figure 43. Data Collection CF 3

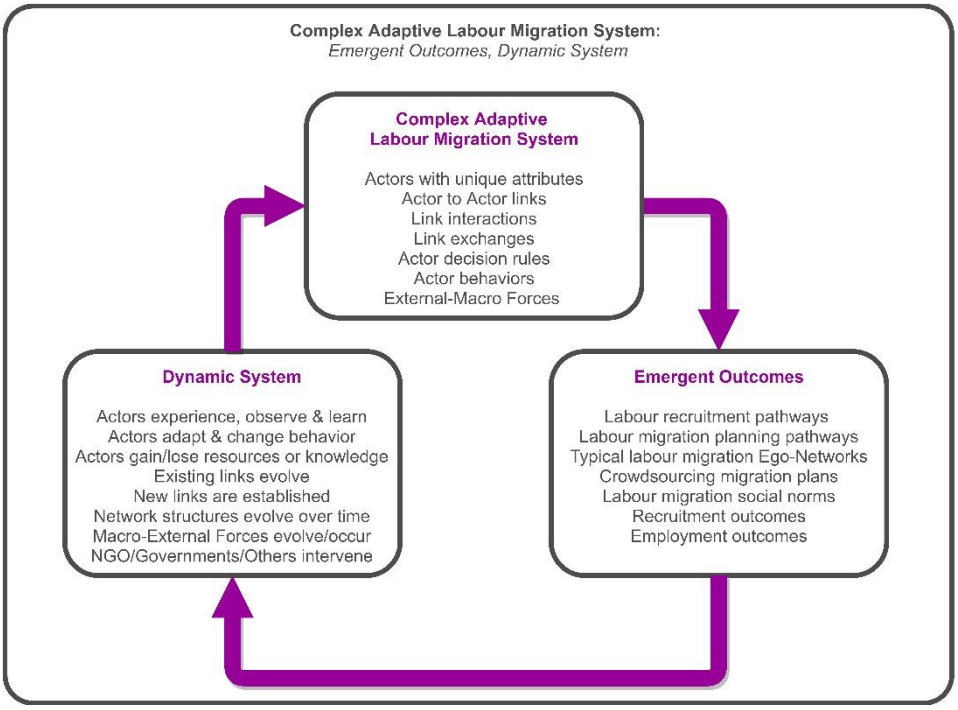


Figure 44. Data Collection CF 4

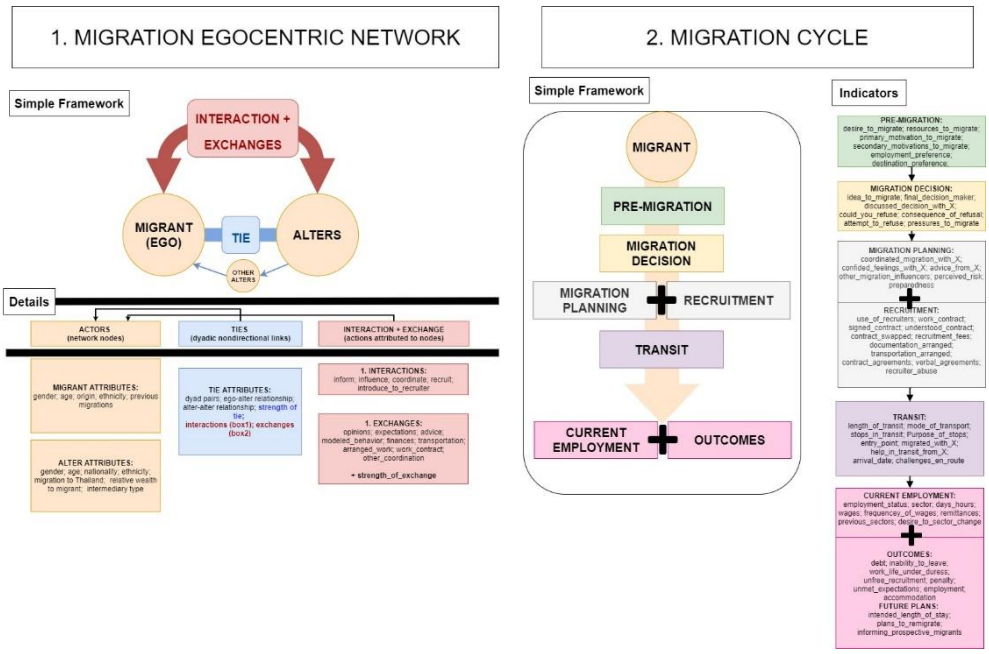
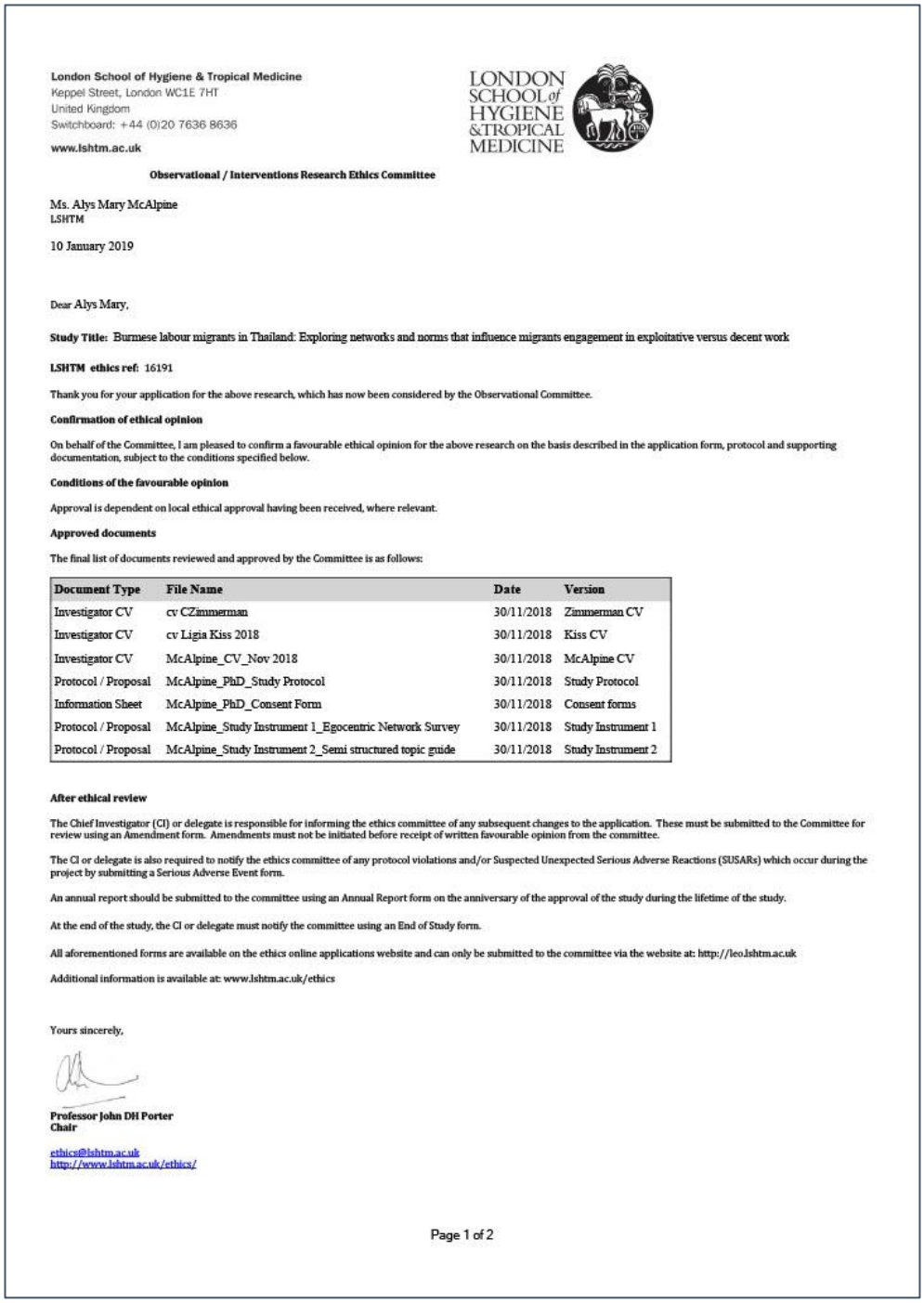


Figure 45. Data Collection CF 5

A.3 Ethics approvals

This research received Ethics Committee approval from London School of Hygiene and Tropical Medicine (see A.3.1) and the Institute for the Development of Human Research Protections (see A.3.2). For the latter, I attended an in-person interview with the Ethics Committee on 21-01-2019.

A.3.1 LSHTM ethical approval



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Switchboard: +44 (0)20 7636 8636
www.lshtm.ac.uk

LONDON SCHOOL of HYGIENE &TROPICAL MEDICINE

Observational / Interventions Research Ethics Committee

Ms. Alys Mary McAlpine
LSHTM

10 January 2019

Dear Alys Mary,

Study Title: Burmese labour migrants in Thailand: Exploring networks and norms that influence migrants engagement in exploitative versus decent work

LSHTM ethics ref: 16191

Thank you for your application for the above research, which has now been considered by the Observational Committee.

Confirmation of ethical opinion

On behalf of the Committee, I am pleased to confirm a favourable ethical opinion for the above research on the basis described in the application form, protocol and supporting documentation, subject to the conditions specified below.

Conditions of the favourable opinion

Approval is dependent on local ethical approval having been received, where relevant.

Approved documents

The final list of documents reviewed and approved by the Committee is as follows:

Document Type	File Name	Date	Version
Investigator CV	cv CZimmerman	30/11/2018	Zimmerman CV
Investigator CV	cv Ligia Kiss 2018	30/11/2018	Kiss CV
Investigator CV	McAlpine_CV_Nov 2018	30/11/2018	McAlpine CV
Protocol / Proposal	McAlpine_PhD_Study Protocol	30/11/2018	Study Protocol
Information Sheet	McAlpine_PhD_Consent Form	30/11/2018	Consent forms
Protocol / Proposal	McAlpine_Study Instrument 1_Egocentric Network Survey	30/11/2018	Study Instrument 1
Protocol / Proposal	McAlpine_Study Instrument 2_Semi structured topic guide	30/11/2018	Study Instrument 2

After ethical review

The Chief Investigator (CI) or delegate is responsible for informing the ethics committee of any subsequent changes to the application. These must be submitted to the Committee for review using an Amendment form. Amendments must not be initiated before receipt of written favourable opinion from the committee.

The CI or delegate is also required to notify the ethics committee of any protocol violations and/or Suspected Unexpected Serious Adverse Reactions (SUSARs) which occur during the project by submitting a Serious Adverse Event form.

An annual report should be submitted to the committee using an Annual Report form on the anniversary of the approval of the study during the lifetime of the study.

At the end of the study, the CI or delegate must notify the committee using an End of Study form.

All aforementioned forms are available on the ethics online applications website and can only be submitted to the committee via the website at: http://leo.lshtm.ac.uk

Additional information is available at: www.lshtm.ac.uk/ethics

Yours sincerely,

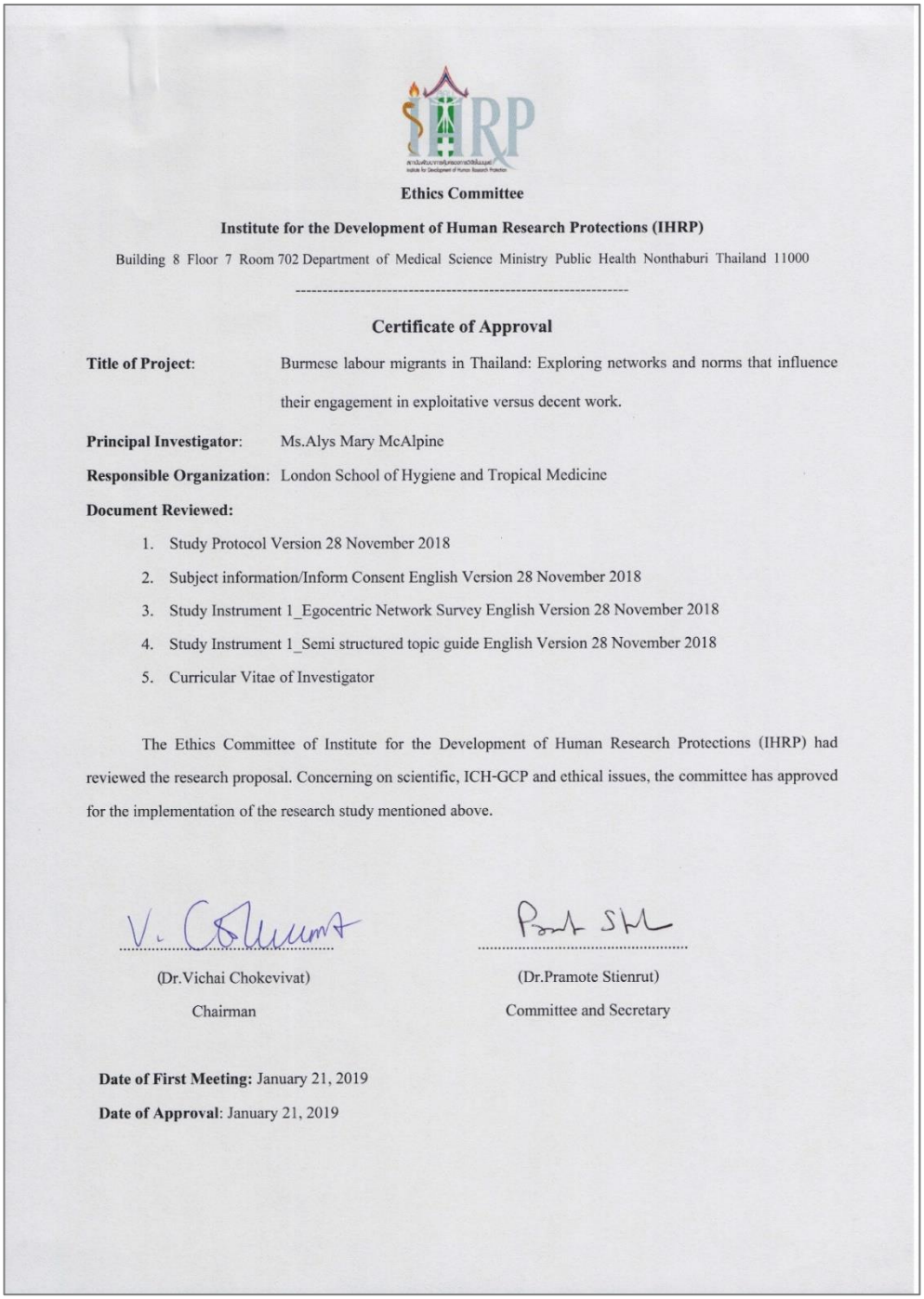
Professor John DH Porter
Chair

ethics@lshtm.ac.uk
http://www.lshtm.ac.uk/ethics/

Page 1 of 2

Figure 46. LSHTM ethics approval letter for study

A.3.2 Institute for the Development of Human Research Protections (IHRP)



Ethics Committee

Institute for the Development of Human Research Protections (IHRP)

Building 8 Floor 7 Room 702 Department of Medical Science Ministry Public Health Nonthaburi Thailand 11000

Certificate of Approval

Title of Project: Burmese labour migrants in Thailand: Exploring networks and norms that influence their engagement in exploitative versus decent work.

Principal Investigator: Ms.Alys Mary McAlpine

Responsible Organization: London School of Hygiene and Tropical Medicine

Document Reviewed:

1. Study Protocol Version 28 November 2018
2. Subject information/Inform Consent English Version 28 November 2018
3. Study Instrument 1_Egocentric Network Survey English Version 28 November 2018
4. Study Instrument 1_Semi structured topic guide English Version 28 November 2018
5. Curricular Vitae of Investigator

The Ethics Committee of Institute for the Development of Human Research Protections (IHRP) had reviewed the research proposal. Concerning on scientific, ICH-GCP and ethical issues, the committee has approved for the implementation of the research study mentioned above.

(Dr.Vichai Chokevivat)
Chairman

(Dr.Pramote Stienrut)
Committee and Secretary

Date of First Meeting: January 21, 2019

Date of Approval: January 21, 2019

Figure 47. IHRP ethics approval letter for study

Appendix 4.1 - 4.3 are the same documentation as the 'Supplementary Material 1-3' documentation for the published version of Paper 1 in the *Journal of Computational Social Science*.

A.4.1 Systematic review search protocol

Caption: This Systematic Review Search Protocol outlines the main aim and objectives. It also presents the key search terms (Table 34) and the search strategy for this review, including the inclusion/exclusion criteria which have also been formatted into a Screening Checklist tool (Table 35). We have also added details on the bibliographic databases searches (Table 36).

Working title: Exploring migration pathways, labour migration and modern slavery using agent-based modelling: a systematic review

Key words: migration, modern slavery, trafficking, child labour, dynamic modelling, network analysis, agent-based modelling

Authors: Alys McAlpine (AM), Ligia Kiss (LK), Cathy Zimmerman (CZ) and Zaid Chalabi (ZC)

Aim: To review the use of agent-based modelling in research exploring migration pathways, labour migration and all forms of modern slavery to assess the applications of these methods of research on these topics and lessons learned, as well as identify the appropriateness and opportunities in these methodologies going forward.

Objectives:

- To inventory the use of agent-based modelling methodologies in research on topics pertaining to migration and modern slavery;
- To conduct a focused review of any research aims, research questions or analysis indicators pertaining to migrants entry into work, labour exploitation, modern slavery, or migrant workers' health outcome;

- To summarise the applications of the methods used in the included studies;
- To outline the lessons learned and articulated in the results and discussions;
- To assess and summarise the gaps, opportunities and limitations of these methods as identified by the authors of the included studies and the authors of this systematic review.

Systematic Review Methodology:

We will follow the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. The search strategy will be a two-concept search (with the use of NOT terms). We will run the search in 5 bibliographic databases (PubMed; Scopus ; Web of Science; MathSci Net; ACM Digital Library). Table 34 outlines the key search terms and Table 35 outlines the inclusion criteria for the screeners (AM + LK).

Table 34. Systematic review protocol – search terms

Concept 1: migration; low-wage or hazardous labour; labour recruitment; modern slavery or human smuggling	Concept 2: complex system simulations; network analysis
1: MIGRATION migrat* OR migrant* OR immigrat* OR immigrant* emigrat* OR emigrant*OR refugee* OR assylum OR "internal* displace*" OR (displace* NEAR/4 people*) OR (displace* NEAR/4 population*) humanitarian 2: LOW-WAGE OR HAZARDOUS LABOUR "low-wage" OR "low-skill" OR (occupation* NEAR/4 (health OR safety)) OR "trade union*" 3: labour RECRUITMENT labo$r recruit* OR labo$r broker* OR lab$or agent OR labo$r intermediar* OR "labo$r market*" OR "labo$r supply" 4: MODERN SLAVERY (human NEAR/4 traffick*) OR (human NEAR/4 smuggl*) OR (migrant* NEAR/4 traffick*) OR (migrant* NEAR/4 smuggl*) OR (refugee NEAR/4 traffick*) OR (refugee NEAR/4 smuggl*) OR "modern slave*" OR "forced labo$r*" OR "forced work*" OR "child labo$r*" OR "child work*" OR (child NEAR/4 traffick*) OR "bonded labo$r*" OR "bonded work*" OR "debt bond*" OR "unfree labo$r" OR "labo$r NEAR/4 (exploit* OR abus*)" OR "early marriage*" OR "child marriage*" OR "child bride*" OR "forced marriage*" OR "forced bride*" OR (bride NEAR/4 traffick*) OR "forced conscription" OR "child soldier*" OR "rebel wives"	**Dynamic:** "agent-based model*" "individual-based model*" "stochastic-dynamic model*" "computational agent*" "cellular-automata*" "social simulat*" microsimulat* ("machine learning" NEAR/4 "dynamic system*") (system* NEAR/4 "interact* object*") "system dynamics" "complex system* simulation" "complex system* model*" "discrete-event simulation" "discrete-time Markov chains" **Static:** "network analysis" "network data" "network model*" "bayesian network"
NOT :(cancer* OR tumo$r* OR protein* OR gene OR genetic OR genomic* OR oncolog* OR immunolog* OR "earth-system* model*" OR "oceanic-migration*" OR "bird NEAR/4 migrat*" OR "fish-migration" OR species OR "cell-migrat*" OR breed* OR molecul* OR bacteria* OR particle* OR "cell-cell" OR tissue OR larva* OR ecosystem* OR egg* OR predator* OR sedement*)	

Table 35. Systematic review protocol – screening checklist

Inclusion Criteria ***Checklist Question***	**Yes/No**
1: DOCUMENT TYPE: Peer reviewed articles **Excluding:** reviews; conference abstracts; books or grey literature ***Is this a peer-reviewed article?***	**[Y] [N]**
2: PUBLICATION DATE: Between 1 January 1999 and the dates of the database searches (described later in this protocol) ***Was this study published on or after January 1, 1999 and search dates?***	**[Y] [N]**
3: METHODOLOGY: **Phase 1:** Must describe use of either a complex systems modelling approach or network analysis (phase 1 inclusion) and then agent-based modelling only for extraction (phase 2 inclusion). **Including:** ABM, IBM, SDM, cellular-automata, microsimulation, dynamic system modelling, Bayesian network analysis, discrete-event simulation, discrete-time Markov chains, diffusion models, machine-learning, or any form of network analysis or simulations. **Phase 2:** Must present an original agent-based model and use the 'agent-based modelling' terminology to describe the methods. **Note:** 1. Any methodology that you think might be relevant or included please include at the abstract screening stage and the co-reviewers can discuss and iterate the methodology inclusion criteria before full article screening. 2. The final yield will then be divided by dynamic and static studies to extract separately and write up as 2 papers. ***Phase 1: Does the study use either complex systems simulations or network analysis methods?*** ***Phase 2: Does the study use agent-based modelling?***	**[Y] [N]** **[Y] [N]**
4: RESEARCH QUESTIONS: The article or review must address at least one of the following topics in the simulations or network analyses described: ● Migration corridor trends, migration patterns and drivers of migration *(including: short/long term, seasonal, permanent resettlements, internal or international, rural to urban, economic migrants, student migrants, distress migrants (refugees/asylum seekers/internally displaced persons) and migrant workers of any work type or wage level.* ● Rural to urban migration ● Migrant social networks relevant to involved in migration planning, implementation or job/earning seeking at destination ● Migrant workers and work outcomes, including work recruitment ● Migration policy or broader policy areas impact on migration ● Safer labour migration or migrant worker health interventions that have individual or migrant specific outcomes (not NGO service network)	**[Y] [N]**

• Remittance flow • Return migration • Modern slavery or child labour (including child soldiers) ***Does this study address relevant research question(s) or analysis relevant to migration mechanisms or modern slavery?***	
Total number of 'No' answers? 0=include; 1+=exclude	**# of N?**
Examples of excluded topics: • Disease spread through migration • Migrant population health at destination (unless specific to migrant workers or slavery) • Humanitarian coordination or service delivery broadly (will include safer labour migration research) • Disaster preparedness or short-term emergency evacuation • Residential or local migration (for example, urban sprawl, neighbourhood choice, etc) • Urban sprawl without focus on migration as driving force • Low-wage or hazardous occupation research that is not disaggregated by migrant status • ***NOTE:** We will not apply any exclusion criteria based on the data source (quantitative, qualitative, secondary, theoretical, etc.), study type (cross-sectional, longitudinal, trial, etc.), quality of the study, language or journal.	

This systematic review includes 5 bibliographic databases. The search strategy was developed and tested on the bibliographic database with the largest source list, Web of Science, to ensure relevance of search terms and revise any issues with phrases, truncation, proximity functions or Boolean operators (see Table 36).

Table 36. Systematic review protocol – bibliographic database search scripts

1) Web of Science
TERM 1: (migrat* OR migrant* OR immigrat* OR immigrant* OR emigrat* OR emigrant* OR "internal* displace*" OR (displace* NEAR/4 people*) OR (displace* NEAR/4 population*) OR refugee* OR asylum* OR humanitarian OR "low-wage" OR "low-skill" OR (occupation* NEAR/4 (health OR safety)) OR "trade union*" OR labo$r recruit* OR labo$r broker* OR lab$or agent OR labo$r intermediar* OR "labo$r market*" OR "labo$r suppl*" OR "work* stirke*" OR "labo$r strike*" OR (human NEAR/4 traffick*) OR (human NEAR/4 smuggl*) OR (migrant* NEAR/4 traffick*) OR (migrant* NEAR/4 smuggl*) OR (refugee NEAR/4 traffick*) OR (refugee NEAR/4 smuggl*) OR "modern slave*" OR "forced labo$r*" OR "forced work*" OR "child labo$r*" OR "child work*" OR (child NEAR/4 traffick*) OR "bonded labo$r*" OR "bonded work*" OR "debt bond*" OR "unfree labo$r" OR (labo$r NEAR/4 (exploit* OR abus*)) OR "early marriage*" OR "child marriage*" OR "child bride*" OR "forced marriage*" OR "forced bride*" OR (bride NEAR/4 traffick*) OR "forced conscription" OR "child soldier*" OR "rebel wives" OR "manpower compan*" OR "foreign labo$r*" OR "foreign work*" OR "seasonal labo$r*" OR "seasonal work*") **TERM 2: AND** ("agent-based model*" OR "individual-based model*" OR "stochastic-dynamic model*" OR "computational-agent*" OR "cellular-automata*" OR "network analysis" OR "network data" OR "network model*" OR "social simulat*" OR microsimulat* OR ("machine learning" NEAR/4 "dynamic system*") OR (system* NEAR/4 "interact* object*") OR "system dynamics" OR "bayesian network" OR "complex system* simulation" OR "complex system* model*" OR "discrete-event simulation" OR "discrete-time Markov chains") **TERM 3: NOT** (cancer* OR tumo$r* OR protein* OR gene OR genetic OR genomic* OR oncolog* OR immunolog* OR "earth-system* model*" OR "oceanic-migration*" OR "bird NEAR/4 migrat*" OR "fish-migration" OR species OR "cell-migrat*" OR breed* OR molecul* OR bacteria* OR particle* OR "cell-cell" OR tissue OR larva* OR ecosystem* OR egg* OR predator* OR sediment*) **Search Date:** 09 June 2019 YIELD= 1165 **Filters:** Document Type: Article or Review; Years: 1999-2019; Language: All
2) ArXiv
TERM 1: ("human trafficking" OR migrat* OR migrant OR immigra* OR refugee OR asylum OR slavery) **TERM 2: AND** "agent-based" OR "individual based" OR "stochastic dynamic" OR "cellular-automata" OR "network analysis" OR microsimulat* OR "system dynamics" OR bayesian OR "discrete-event" OR "discrete-time" **TERM 3: NOT:** cancer OR cancerous OR tumor OR tumour OR protein OR gene OR genetic OR genomics OR oncology OR oncological OR immunology OR "earth-system" OR "oceanic-migration" OR "bird migration" OR "fish migration" OR species OR "cell-migration" OR breed OR molecule OR molecular OR bacteria OR bacterial OR particle OR "cell-cell" OR tissue OR larva OR larval OR ecosystem OR egg OR predator OR sediment OR sedimentary **Search Date:** 18 Sept 2019 YIELD= 127 **Filters:** Document Type: Article or Review; Years: 1999-2019; Language: All

3) MathSciNet

TERM 1: (human trafficking or migrat* or migrant or immigra* or refugee or asylum or slavery)

TERM 2: AND ("agent-based" or "individual based" or microsimulation or automata or dynamic or network)

Search Date: 18 Sept 2019 YIELD= 74
Filters: Document Type: Article or Review; Years: 1999-2019; Language: All

4) SCOPUS:

TERM 1: (migrat* OR migrant* OR immigrat* OR immigrant* OR emigrat* OR emigrant* OR "internal* displace*" OR (displace* W/4 people*) OR (displace* W/4 population*) OR refugee* OR asylum* humanitarian OR "low-wage" OR "low-skill" OR (occupation* W/4 health) OR (occupation* W/4 safety) OR "trade union*" OR labo*r recruit* OR labo?*r broker* OR lab*or agent OR labo*r intermediar* OR "labo*r market*" OR "labo*r suppl*" OR "work* stirke*" OR "labo*r strike*" OR (human W/4 traffick*) OR (human W/4 smuggl*) OR (migrant* W/4 traffick*) OR (migrant* W/4 smuggl*) OR (refugee W/4 traffick*) OR (refugee W/4 smuggl*) OR "modern slave*" OR "forced labo*r*" OR "forced work*" OR "child labo*r*" OR "child work*" OR (child W/4 traffick*) OR "bonded labo*r*" OR "bonded work*" OR "debt bond*" OR "unfree labo*r" OR (labo*r W/4 exploit*) OR (labo*r W/4 abus*) OR "early marriage*" OR "child marriage*" OR "child bride*" OR "forced marriage*" OR "forced bride*" OR (bride W/4 traffick*) OR "forced conscription" OR "child soldier*" OR "rebel wives" OR "manpower compan*" OR "foreign labo*r*" OR "foreign work*" OR "seasonal labo*r*" OR "seasonal work*")

TERM 2: AND (“agent-based model*” OR “individual-based model*” OR “stochastic-dynamic model*” OR “computational-agent*” OR “cellular-automata*” OR “network analysis” OR “network data” OR “network model*” OR “social simulat*” OR microsimulat* OR (“machine learning” W/4 “dynamic system*”) OR (system* W/4 “interact* object*”) OR “system dynamics” OR “bayesian network” OR “complex system* simulation” OR “complex system* model*” OR “discrete-event simulation” OR “discrete-time Markov chains”)

Search Date: 09 June 2019 YIELD= 148
Filters: Document Type: Article or Review; Years: 1999-2019; Language: All

5) Pub-Med

TERM 1: (migrate OR migrant OR migration OR immigrate OR immigrant OR immigration OR emigrate OR emigrant OR emigration OR “internal displacement” OR “internally displaced” OR “displaced people” OR “displaced population” OR refugee OR asylum OR humanitarian OR “low-wage” OR “low-skill” OR “occupational health” OR “occupational safety” OR “trade union” OR “labour recruitment” OR “labor recruitment” OR broker OR intermediary OR intermediaries OR “labour market” OR “labor market” OR “labour supply” OR “labor supply” OR “workers strike” OR “human trafficking” OR “human traffickers” OR “human smuggling” OR “human smugglers” OR ‘modern slavery’ OR “forced labor” OR “forced labour” OR “child labor” OR “child labour” OR “child work” OR “child workers” OR “bonded labor” OR “bonded labour” OR “bonded work” OR “bonded workers” OR “debt bondage” OR “unfree labor” OR “unfree labour” OR “labor exploitation” OR “labour exploitation” OR “labor abuse” OR “labour abuse” OR “early marriage” OR “child marriage” OR “child bride” OR “forced marriage” OR “forced bride” OR “forced conscription” OR “child soldier” OR “rebel wives” OR “manpower company” OR “manpower companies” OR “foreign labor” OR “foreign labour” OR “foreign work” OR “foreign workers” OR “seasonal labor” OR “seasonal labour” OR “seasonal work” OR “seasonal workers”)

TERM 2: AND (“agent-based model” OR “agent-based modelling” OR “individual based model” OR “individual based modelling” OR “stochastic dynamic model” OR “stochastic dynamic modelling” OR “computational agent” OR “cellular-automata” OR “network analysis” OR “network data” OR “network model” OR “social simulation” OR microsimulation OR “machine learning” OR “dynamic system” OR “interaction object” OR “system dynamics” OR “bayesian network” OR “complex system simulation” OR “complex system model” OR “complex system modelling” OR “discrete event simulation” OR “discrete time Markov chains”)

TERM 3: NOT: (cancer OR cancerous OR tumor OR tumour OR protein OR gene OR genetic OR genomics OR oncology OR oncological OR immunology OR “earth-system” OR “oceanic-migration” OR “bird migration” OR “fish migration” OR species OR “cell-migration” OR breed OR molecule OR molecular OR bacteria OR bacterial OR particle OR "cell-cell" OR tissue OR larva OR larval OR ecosystem OR egg OR predator OR sediment OR sedimentary)

Search Date: 09 June 2019 YIELD= 402
Filters: Document Type: Classical Articles or Reviews; Years: 1999-2019; Language: All

A.4.2 Exclusion process

Caption: This additional material provides an overview of relevant studies not included in this systematic review's data extraction.

This review first included only studies that reported an original agent-based model and used this 'agent-based modelling' terminology to describe it. We identified 8 studies that described modelling techniques justifiably relevant to this review but did not meet the criteria of clearly defining the model as an 'agent-based model'. Table 37 inventories those eight articles.

Table 37. Borderline excluded articles

First Author	Year	Article Title
Biondo	2012	*Return Migration After Brain Drain: A Simulation Approach*
Bocedi	2012	*Uncertainty and the Role of Information Acquisition in the Evolution of Context-Dependent Emigration*
Camacho	2019	*A model in continuous time and space to study economic migration*
Demurger	2009	*Migrants as second-class workers in urban China? A decomposition analysis*
Li	2017	*The influence of migration speed on cooperation in spatial games*
Marchiori	2011	*The impact of migration on origin countries: a numerical analysis*
Schweitzer	2012	*Optimal migration promotes the outbreak of cooperation in heterogeneous populations*
Werpachowska	2016	*Microsimulations of demographic changes in England and Wales under different EU referendum scenarios*

A.4.3 Full data extraction tables

Caption: An additional Excel CSV file has also been submitted with this article, which includes an aggregated data extraction table presenting the same content found in the Results tables in the article text for the option to review the extracted data for one article across all tables in a single view.

Access here or via the open access paper here:

McAlpine A, Kiss L, Zimmerman C, Chalabi Z. Agent-based modelling for migration and modern slavery research: a systematic review. Journal of Computational Social Science. 2021;4,243–332. https://doi.org/10.1007/s42001-020-00076-7

A.5 Paper 2: MMSNA data collection tool – Supplementary materials

Appendix 5 offers some additional documentation of the MMSNA tools descripted in Paper 2 of this thesis. These explanations were beyond the scope

A.5.1 MMSNA data collection tool overview

The participatory egocentric network mapping tool was built for Android tablets. The survey consists of two independent parts: 1) an informed consent form with digital signature-capturing capacities; and 2) the survey comprised of an ordered set of 11 thematic subsections. The survey sections are a mix of structured and unstructured (open-ended, qualitative) questions. The interviewer can conduct the entirety of the interview using just the tablet and audio-recorder since the informed consent, survey questions, prompts, interviewer scripts and answer-entry are all programmed into the application. The tool is built on top of the open-source application framework OpenDataKit (218). ODK has two framework options. ODK Standard, which aims to eliminate the need for software engineering skills when developing data management applications for research and ODK2, which allows for advanced web programmers to implement entirely custom interfaces and functionality into ODK research workflows. The tool uses ODK2 (now named ODK-X) to take advantage of adding custom functionality to a trusted codebase.

By separating the survey content (in English and Burmese) and survey logic into formatted excel files and the application logic, database, and interface into a connected, but separate codebase (JavaScript, HTML, CSS), our team of researchers, translators, and software developer could work simultaneously on our separate areas for the project.

By using the D3js JavaScript library within ODK2, we created custom egocentric network interfaces from a force-directed graph layout (297). The interfaces both display and manipulate the ODK2 database while providing real time accurate visual feedback for the interviewer and migrant. This real time feedback functioned, in part, as a verification process for data

submission and consistently provided the 'whole picture' throughout the interview to encourage comparative exploration. This participatory process of interviewer-participant co-authorship can encourage a continual process of data verification as the data are regularly viewed and reviewed in real time and can encourage structured, yet unique narrative pathways in the survey as the visual representation can display connections and patterns not immediately obvious when the data are solely represented in text, audio, or static imagery after survey completion.

We chose a specific visual 'language' for the interface within the survey that included limited unambiguous text and the fewest number of forms and least amount of colour to represent the temporal, monetary, and social structures of an individual's migration process. As a constant, the migrant is always located in the centre of the graph and always represented by an orange-coloured circle. This underlines the migrant as the tenable focal point of the interview. Individuals added to the migrant's network are always white coloured circles but gain additional coloured rings that represent temporary roles that the individual embodies within the context of the interview. Individuals can have zero or more rings. Individuals who function as intermediaries for this migration process gain a small dark grey ring, individuals who function as intermediaries generally but not actively involved in the migration being described gain a small translucent grey ring. Individuals who were the first employer for the migrant after arrival in Thailand gain a large dark blue ring, individuals who functioned as subsequent employers for the migrant gain a large translucent blue ring. This is intended to underline that these are temporary roles that these individuals play in different temporal stages. When a connection between a migrant and an individual involves monetary exchange, the connection line gains a partial red marker (dark red for debts at time of arrival in Thailand, transparent red for payments). For connections that involve money going out from the migrant a partial green marker (dark green for gift, transparent green for loan) is added to the connection line. Excluding all other data,

these basic elements can help form a useful visual model of a migrant's migration process for immediate use during interview probing.

For conducting interviews in remote locations, ODK2's database does not require connecting to a remote network or server during or after the interview process. This allows interviews to be conducted entirely offline in low-connectivity and resource-constrained locations during our data collection phase in Thailand. After interviews, we securely exported the collected data to two separate locations: an onsite encrypted hard drive and an encrypted Keybase folder managed by our research team (298).

The MMSNA data collection tool was designed to assist in participatory collection of network data from Myanmar labour migrants in Thailand. As we conceptualised and developed the idea of a tablet-based egocentric network survey we set out to meet the following objectives:

1. Collect individual-level data on migrants' personal networks involved in their migration process, including the attributes of individuals in their network, links between individuals in their network and the dynamic evolution of the network throughout the individual's stages of migration;
2. Collect a large amount of network data as efficiently as possible;
3. Minimise the cognitive burden for the interviewers and interviewees in retaining the network narrative for further probing;
4. Enhance the interviewers' and interviewees' understanding of the research objectives by providing a visual tool that helps present the network concept;
5. Allow for participatory knowledge-production by designing a tool that encouraged the interviewee to be part of building the visual network map;
6. Create an opportunity to check quality of data input where the interviewees could see and correct any errors in the network visual;
7. Deepen our understanding of labour migration networks through a personalised visual interview prop to tailor the interview probes to the interviewees egocentric network.

A.5.2 MMSNA data collection tool piloting notes

We conducted two rounds of pilot interviews (n=5 interviews in total) two weeks apart in two different locations (Mahachai and Khao Lak). These pilot interviews allowed us to iterate the tool between the two pilot sessions. The pilot interviews were conducted in the same way that the study interviews were designed. Each was conducted in a private one-on-one interview setting with the tablet-administered application and audio-recorder. The interviewers were trained and instructed not to focus solely on completing the interview but to use cognitive-interviewing methods to check the concepts and questions were being comprehended as well as to note any practical challenges with the survey tool (responsiveness, navigation, readability, timing, etc.). Below we outline some of the key lessons specifically relevant to the development and testing of the tool application:

- Originally, the interview was divided into two parts, Part 1 was the egocentric network mapping and Part 2 was the semi-structured qualitative interview. During the first round of pilot interviews, we learned that the process of mapping the egocentric network can become a probing opportunity where individuals describe the characteristics of the relationship or interactions. The interviewers explained how a significant amount of relevant qualitative data is lost if we do not audio record that mapping process and that the mapping could be an opportunity to build specific open-ended probing into that structured mapping portion of the interview.
    - **Updates made**: We decided to merge the two parts of the interview and to take a mixed methods approach to not just the study but the interview process as well. This came with certain challenges for the researchers switching between structure and unstructured questions. It also meant there was some duplication between recorded and tablet-entered data, but we plan to use this for quality checking and conducting further process reviews on the use of the tool. We

also added extensive training with the researchers on how the network graph is not just collected data but seconds as a visual probing tool in the interview.

- We tested using the tool on an 8-inch tablet and found the screen size to be too small to easily navigate the survey and to easily see the network visualisation.
    - **Updates made**: We transitioned the tool to larger 10-inch tablet with stylus.
- Through cognitive interviewing we learned that there are a range of terms to describe migration intermediary actors (in English these translate vaguely to broker, formal agent, coordinator/helper, smuggler, trafficker).
    - **Updates made**: We determined that we needed node-classifying questions that followed the name-generating questions to try and sort how the interviewee would categorise his or her intermediaries according to this range of actor terminology.
- For some of the questions in the Burmese version there were questions or answers cut off by the side of the screen since the Burmese script does not require the same regular spacing between words.
    - **Updates made**: We reviewed the questions again with a translator specifically to create appropriate breaks in longer strings of letters for our specific tablet screen size.
- Through cognitive interviewing we learned that interviewers interacted in a more narrative-focused manner when prompts, questions, and indication text were explicitly stated, and colour coded on screen.
    - **Updates made**: Adding dedicated survey pages with operational statements “start recording” and “stop recording” in bold red text reduced anxiety about operating the audio recording device and reduced frequency of making

cognitive shifts between thinking about the migrant and thinking about operational tasks.

- **Updates made**: Notices to the interviewer are colour coded in orange, primary questions are bold and coloured grey, and secondary questions and probes are ear-marked with orange and coloured light grey.
- **Updates made**: For open ended questions that show the egocentric network graph for reference only (not for selection) the graph is rendered with a subtly thicker default line weight and does not react to click events.

A.5.3 MMSNA data collection tool final sections

Here we include an outline of the 11 survey subsections, the data collected in each subsection and informative notes about how the subsection works.

1. Interview Details:
    a. Collects metadata regarding the interview context (location of interview, interviewer, recruitment mechanism, etc.)
    b. **Note:** To ensure data privacy compliance, the tool prevents the interview (including the questions in Section 1) from beginning without explicit confirmation that the informed consent form is complete.
2. Migrant Attributes:
    a. Collects structured data on the interviewee's demographics and basic characteristics (gender, age, ethnicity, origin location).
3. Previous Migration and Pre-migration:
    a. Collects structured and open-ended data about the interviewee's previous migrations or their close social contacts' previous migrations (whether previous migrations happened, where to, the overall migration experience)
    b. Collects open-ended data about the pre-migration circumstances for this specific migration (employment and

financial situations before migration, motivations to migrate).

c. **Note:** To ensure accurate data for this specific migration process, the tool emphasises the difference between questions about the interviewee's previous migrations and this most recent migration to Thailand.

4. Migration Planning (Participatory ego-network mapping)
    a. **Note:** This is the section that begins the egocentric network mapping. In this process, the 'name-generating questions' include prompts to add nodes (representing social actors or migration intermediary actors) who contributed to the interviewee's migration process to the personalised egocentric network graph.
    b. Collects structured data about actors involved in the interviewee's migration process throughout the migration cycle (who had the idea for your migration, who gave you advice about migration, who migrated with you, who organised your transportation to Thailand, etc.). Also collects basic demographics and characteristics about each network node (age, gender, relationship to the interviewee, financial status compared to interviewee, measure of weak/strong tie).
    c. **Note:** Additionally, the network graph adds visual markers to nodes (actors) in the egocentric network graph who participated in any monetary exchanges with the interviewee (who did you pay for services, who gave you loans to migrate, etc.). These visual markers can be used by the interviewer for future probing.
    d. Collected data about migration or recruitment intermediaries, brokers, and employers. In this process, the prompts add new intermediaries to the egocentric network graph or selection of pre-existing nodes as intermediaries or employers. Also collects basic demographics and

characteristics about each intermediary or employer network node (age, gender, relationship to the interviewee, financial status compared to interviewee, measure of weak/strong tie).

e. **Note:** Like monetary exchanges, visual markers are added to all intermediaries and employers (distinguishing between the first employer and subsequent employers).

f. Collects open-ended data about the network actors, relationships and migration processes.

5. Broker and Employer:
    a. Collects open-ended data about the interviewee's personal experiences with labour or migration intermediaries (how the interviewee met the intermediary, what services were offered, how the interviewee coordinated with the intermediary, etc.)
    b. Collects open-ended data about the interviewee's general knowledge of labour or migration intermediaries (types of intermediaries, how they work, reputation of intermediaries, how common intermediary use is in origin location, etc.).
    c. **Note:** This section is entirely open-ended audio recorded qualitative questions. The visual egocentric network graph (built in section 4) remains on the tablet screen so the interviewer can use it as a visual probing tool and to recall the interviewee's previous answers).
6. Actor Attributes and Network Connections
    a. Collects additional structured data about node-to-node links in the network graph. In this process, the interviewer and interviewee work together to add a connecting line between each pair of nodes that know each other in some relational capacity and gives that link a relational characteristic (family members, friends, acquaintances, employer/employee, intermediary/migrant, etc.)

b. Collects unstructured data about how these individuals came to know each other (probing on the more unusual connections, for example when an intermediary knows the interviewee's close family or friends).
c. Collects unstructured data on how this network worked together to arrange or advise migration.
d. **Note:** This portion begins to introduce elements of participatory analysis by probing the interviewee to consider the network effect in his or her personal migration story.

7. Migration Transit:
    a. Collects structured data about migration transit and documentation (length of transit, length of time since arrival, documents during transit, documents since arrival, document restrictions).
    b. Collects unstructured data about the migration transit process (modes of transportation, border crossings, resources used for migration transit, and challenges experienced during transit) and immigration documentation (how they organised documentation, use of fraudulent documents).
8. Migration Expectations and Outcomes:
    a. Collects structured data about the pre-migration expectations, agreements about migration details and whether the outcomes of the migration matched the expectations or not. For example, a) Was your employer name agreed before you migrated? b) With whom was [Employer X] agreed? and c) Was your employer at destination the same as Employer X (the one agreed upon)?
    b. **Note:** For questions in part b), the interviewee is able to select a pre-existing node on the egocentric network graph which remains on the tablet screen for the entirety of section
9. Employment in Thailand:

a. Collects structured data about employment at destination (expected employment, actual employment, working days/hours, wages and compensation), occupational safety (work related tasks, protection gear, injuries) and labour abuses (wage deductions, overtime without pay, dangerous work, restricted movement, use of threats, etc.).
b. Collected structured data on violence (threats, damaged belongings, physical violence, sexual violence, forced drug/alcohol use).
c. **Note:** Again, parts of section 9 allow the interviewer and interviewee to select pre-existing nodes on the network visualisation.

10. Migration Reflections and Lessons:
    a. Collects unstructured data about overall migration reflections (how did your experience compare to expectations, overall employment experiences, satisfaction with life and work in Thailand, lessons about migration, ways to make migration safer) and hopes for the future.
11. End of Interview:
    a. Collects structured administrative data about the interview process (any reason for pausing the interview, if the interview happened over multiple days, anyone present in the room besides the interviewer and interviewee).
    b. **Note:** This section is only completed by the interviewer and not read aloud.

A.6 Paper 3: MMSNA study results – Supplementary materials

Appendix 6 provide the supplementary material for Paper 3.

A.6.1 Myanmar-Thailand MOU process

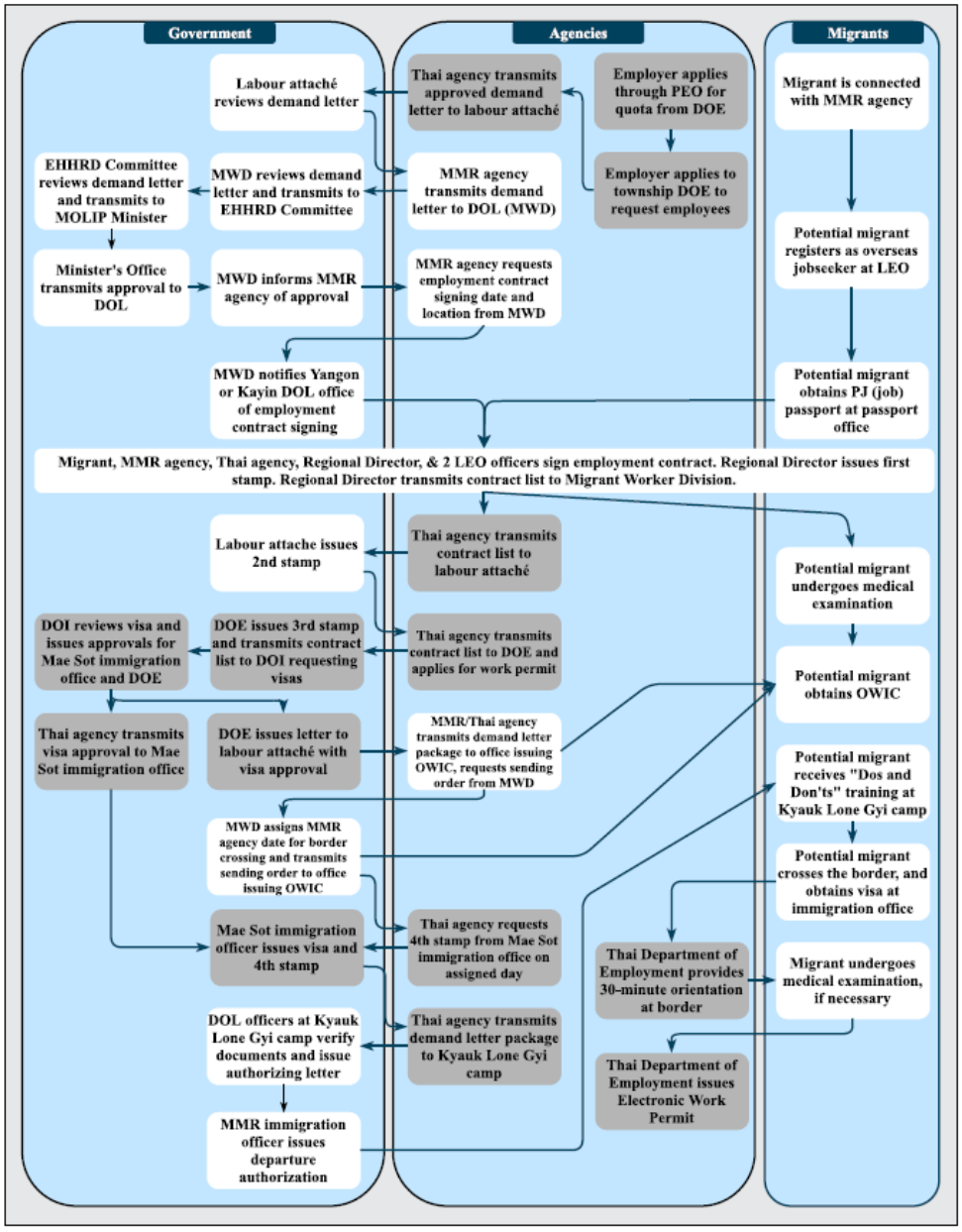


Figure 48. Formal migration under the Myanmar-Thailand MOU, The World Bank (299)

A.6.2 Expanded tables on ego-nets – actor roles and links

Table 38. Alter roles in migration - total and percentages

alter type or Intermediary classification	n		Destination	General Plans	Pre-Travel Docs.	Pre-Travel Contract	Transport Plans	Transport Execution	Accommodate.	Work	Post-Arrival Docs.	Post-Arrival Contract
All alters	903	n	**95**	**173**	**53**	**13**	**134**	**104**	**101**	**119**	**51**	**3**
		row %	**11%**	**19%**	**6%**	**1%**	**15%**	**12%**	**11%**	**13%**	**6%**	**0%**
Social alters	575	n	64	121	24	0	80	35	67	80	9	0
		row %	**11%**	**21%**	**4%**	**0%**	**14%**	**6%**	**12%**	**14%**	**2%**	**0%**
Intermediary alters	122	n	30	51	20	13	50	64	16	30	15	2
		row %	**25%**	**42%**	**16%**	**11%**	**41%**	**52%**	**13%**	**25%**	**12%**	**2%**
Employer alters	206	n	1	1	9	0	4	5	18	9	27	1
		row %	**0.5%**	**0.5%**	**4%**	**0%**	**2%**	**2%**	**9%**	**4%**	**13%**	**0.5%**
Recruiters	29	n	15	10	13	9	12	8	3	13	3	0
		row %	**52%**	**34%**	**45%**	**31%**	**4%**	**28%**	**10%**	**45%**	**10%**	**0%**
Facilitators	86	n	27	44	15	7	39	40	15	28	11	2
		row %	**31%**	**51%**	**17%**	**8%**	**45%**	**47%**	**17%**	**33%**	**13%**	**2%**
Brokers	69	n	23	29	14	5	31	32	16	22	7	1
		row %	**33%**	**42%**	**20%**	**7%**	**45%**	**46%**	**23%**	**32%**	**10%**	**1%**
Helpers	72	n	25	31	10	3	31	18	29	29	5	1
		row %	**35%**	**43%**	**14%**	**4%**	**43%**	**25%**	**40%**	**40%**	**7%**	**1%**
Smugglers	52	n	12	25	2	1	25	33	5	11	4	0
		row %	**23%**	**48%**	**4%**	**2%**	**48%**	**63%**	**10%**	**21%**	**8%**	**0%**
Human Traffickers	18	n	7	10	1	0	6	10	2	5	1	1
		row %	**39%**	**56%**	**6%**	**0%**	**33%**	**56%**	**11%**	**28%**	**6%**	**6%**

Table 39. Ego-Net links

ego-alter links	n	% of links
employer	187	21%
extended family	159	18%
intermediary	122	14%
parent	103	11%
friend	74	8%
close friend	56	6%
sibling	43	5%
neighbour	33	4%
spouse	31	3%
co-worker	22	2%
acquaintance	20	2%
supervisor	19	2%
child	14	2%
fellow migrant	5	1%
community leader	6	1%
friend's friend	8	1%
NGO	1	0.1%
TOTAL	903	

alter-alter links	n	% of links
family	728	43%
employer-employee	243	15%
friends	235	14%
acquaintances	191	11%
close friends	45	3%
intermediary-migrant	75	4%
co-workers	63	4%
intermediary-intermediary	45	3%
intermediary-employer	24	1%
intermediary-social alter	24	1%
employer-social contact	2	0.1%
TOTAL	1,675	

93% of all **Intermediary-Intermediary alter** links were between a facilitator and either a recruiter, smuggler, broker.

A.6.3 Additional illustrative quotes on linked and unlinked intermediaries

Recruiter networks across migration stages and geographies: "The recruiters from Yangon followed with us to Bangkok and they introduced us with the recruiters from Bangkok and they arranged the accommodation for us." (PID 412)

Cross-border smuggling networks only involved in the transit stage: "He brought me from Kawthaung by boat and he sent me to another smuggler . . . we had to wait there for newcomers . . . then our group trekked through the forest to Thailand , when we arrived there, a car came and picked us up, so there were both Burmese and Thai smugglers in my migration." (PID 220) Another interviewee: "I think [the smugglers] worked like a network because the police and drivers were also involved." (PID 513)

Various informal intermediaries that were linked: "The broker who I know is from our village . . . he collaborated with the employer and the police here . . . he also offers money transfer services." (PID 213)

Various informal intermediaries that were not linked: "[Job] facilitation is not associated with those brokers. . . . Once I arrived here, it was my parents' job. They connected me to the employer [and] then I got into a job. That's all." (PID 213)

A.6.4 Network compositions and dynamics

Network compositions ranged in size from 4-23 alters and the network density scores (how connected all the actors were to each other) ranged from 0.06-0.86. Figure 49 provides examples of networks at the extreme ends of the size and density ranges.

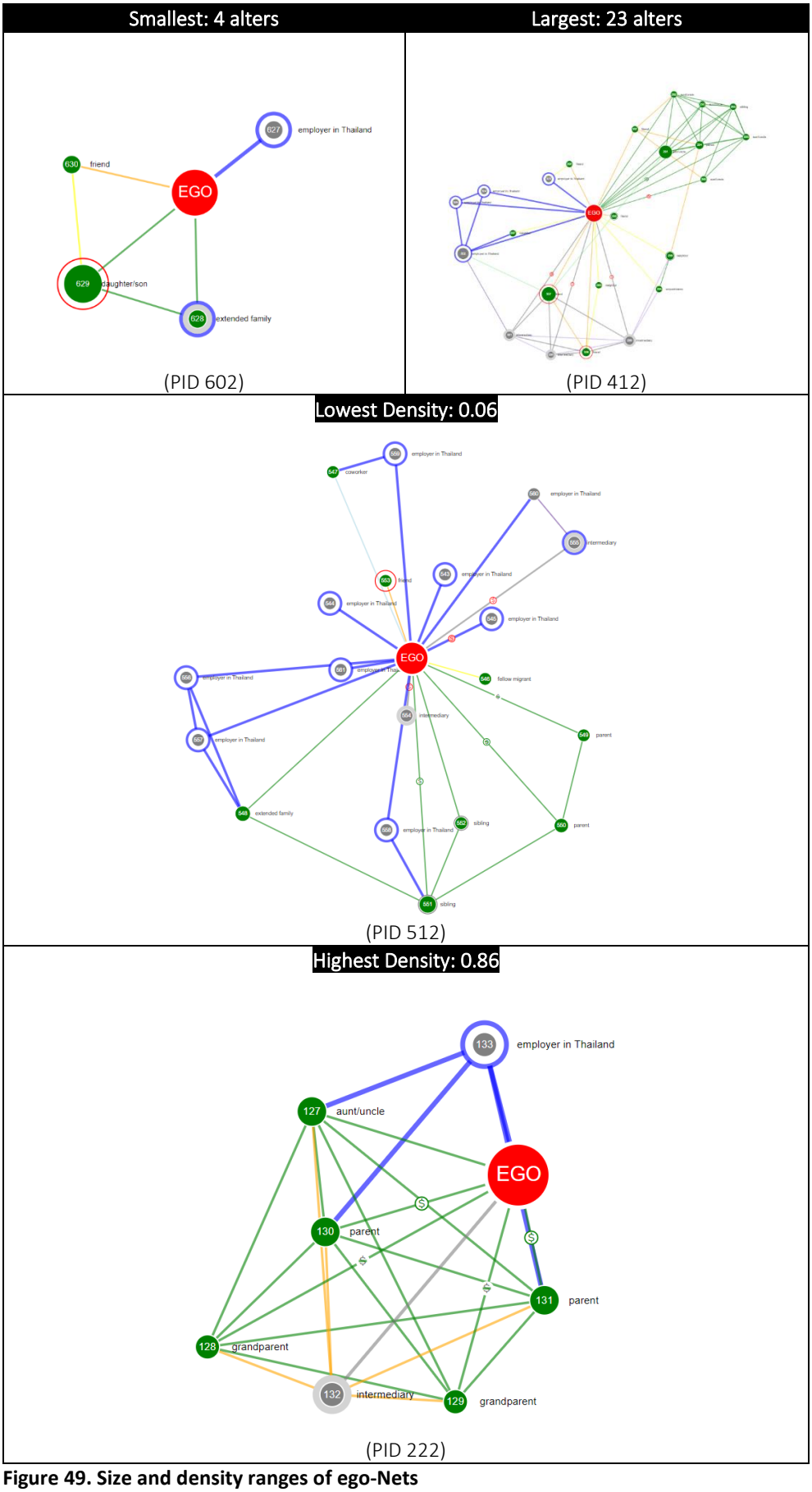


Figure 49. Size and density ranges of ego-Nets

The networks in this sample were dynamic over the migration stages, which means they changed size and composition over the course of the migration trajectory. Some alters were only involved in the early migration stages, for example, social contacts that encouraged migration or gave ego the permission they needed to migrate, while others were not involved until ego arrived at destination, such as new co-workers, supervisors or employers. Intermediaries that were tied to specific processes (transportation, accommodation in transit) were often only briefly connected to ego's network. Different alters' knowledge or services were more pertinent to stages of an individual's migration. Moreover, interactions with one alter sometimes led to unexpected or unplanned connections with other alters. For example, one migrant explained that they did not expect to be stranded in the border town or be offered help by the local shopkeeper, but it was this new connection that resulted in meeting another migrant that connected them to an employer in Mae Sot. Other examples included when facilitators or brokers referred a migrant to other intermediaries. Figure 50 gives one example of a single migration network dissected into 4 sub-networks representing the: 1) decision to migrate; 2) migration planning; 3) transit; and 4) arrival at employment in Thailand.

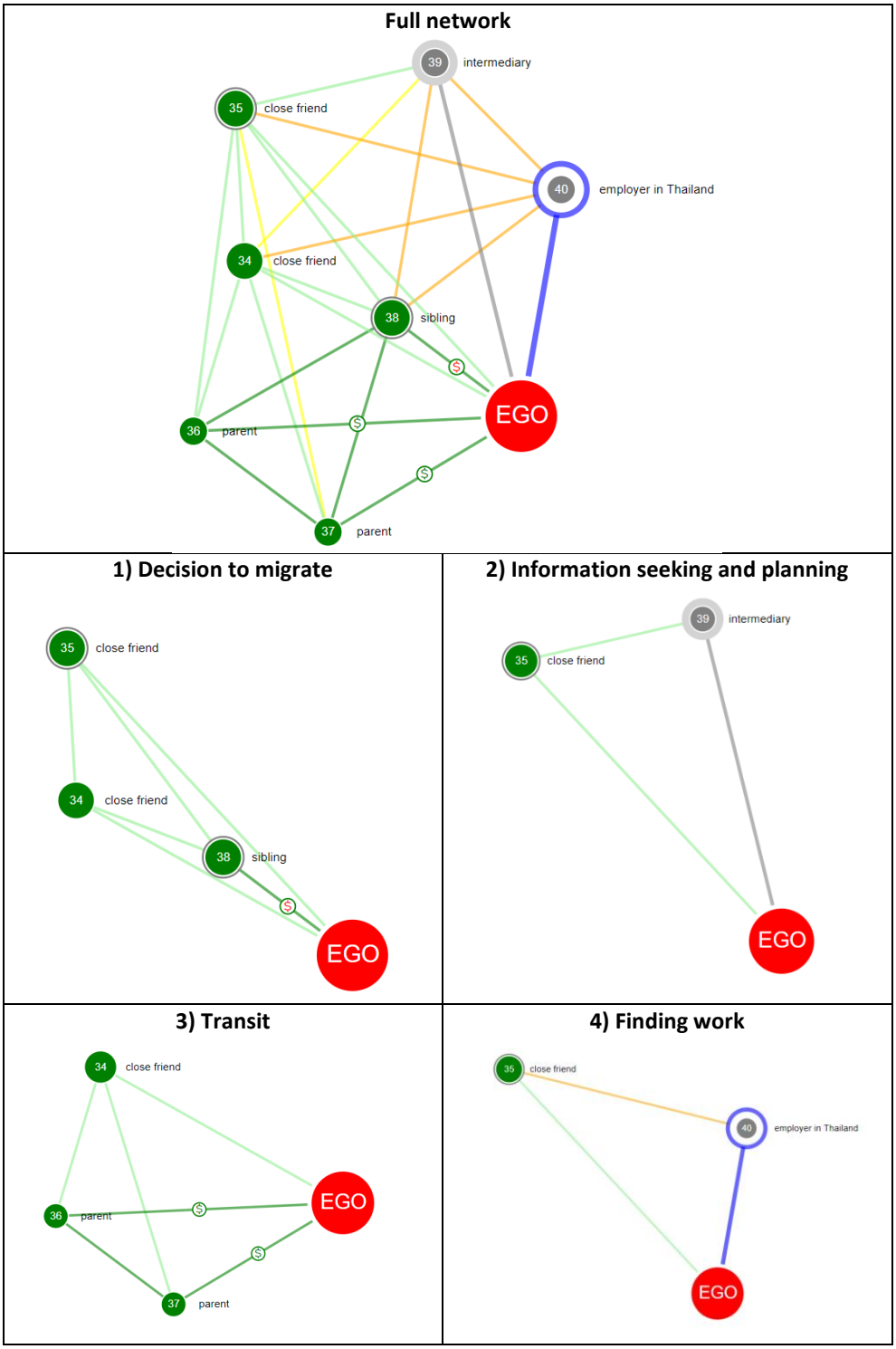


Figure 50. Example of ego-net dynamics over migration stages

In this analysis, it was possible to isolate the individuals who had a financial role. The financial exchange subnetwork in Figure 51 shows a migration ego-net that has been filtered to only the alters that were involved in any financial exchange. These subnetworks consistently included the widest range of alter types and intermediary classifications. They also mapped the way that money is transferred by the migrant and alters that do not have

direct links to each other (e.g., an aunt gives ego money to pay to the intermediary). Social contacts were frequently the source of financial support for the ego's migration, such as giving loans. Intermediaries were commonly paid directly for their services. Employers often charged migrants a debt or reoccurring expenses after they arrived (e.g., accommodation, electricity), commonly in the form of wage deductions. Figure 51 shows one example of how an ego's family members (sibling, grandparent, and aunt) financed her migration so she could pay fees to an intermediary (document 'broker'). The network also shows the employer was deducting expenses from ego's wages, which in turn limited the remittances that ego could send home to family members (grandparent, another aunt). This example also presents a common financial feedback loop that occurs when the social contacts that financed the migration later received remittances from ego (e.g., the grandparent in this example).

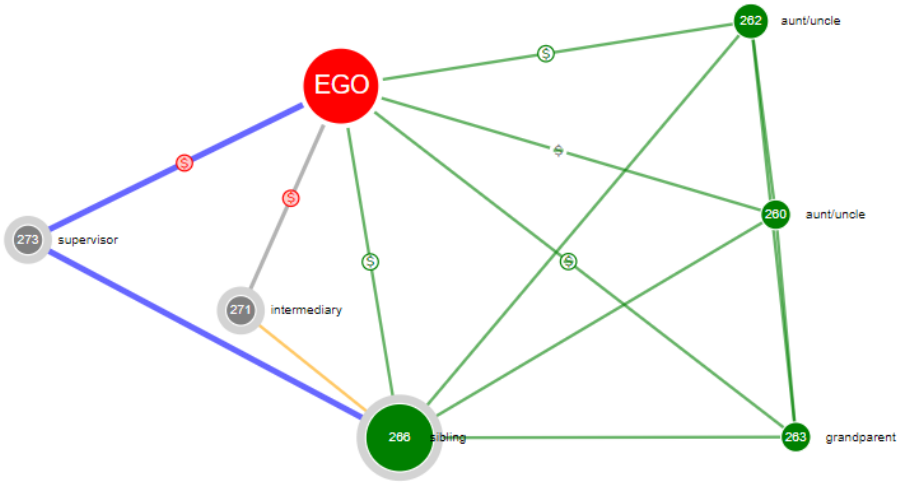


Figure 51. Example of all the financial exchanges in a network

A.7 Paper 4: MyTh MaP-IN ABM ODD+2D protocol

Appendix 7 (A.7) provides additional documentation of the *Myanmar-Thailand Migration Planning & Intermediary Networks* agent-based model (MyTh MaP-IN ABM) using the ODD+2D protocol (A.7.1-A.7.17) along with some additional sections documenting further details on the verification, sensitivity analysis, and validation of the model and outlining future plans (A.7.18-A.7.22). The appendix is divided into four parts.

PART 1. Model summary and team contributions

Part 1 is a short summary of the model and modelling team.

PART 2. ODD+2D Protocol

Part 2 is the ODD+2D[24] protocol for the MyTh MaP-IN ABM (see Table 40).

Table 40. ODD+2D sections

Overview	**A.7.1**	**Purpose and audience**
	A.7.2	**Entities, properties, and scales**
	A.7.3	**Process overview and scheduling**
Design Concepts (+Decisions)	**A.7.4**	**Theoretical and empirical background**
	A.7.5	**Individual decision-making**
	A.7.6	**Learning**
	A.7.7	**Individual sensing**
	A.7.8	**Individual prediction**
	A.7.9	**Interaction**
	A.7.10	**Collectives**
	A.7.11	**Heterogeneity**
	A.7.12	**Stochasticity**
	A.7.13	**Observation**
Details (+Data)	**A.7.14**	**Implementation details**
	A.7.15	**Initialization**
	A.7.16	**Input data**
	A.7.17	**Sub-models**

PART 3. Verification, sensitivity analysis, and validation

Part 3 provides details on the verification, sensitivity analysis, and validation.

A.7.18 Verification
A.7.19 Sensitivity analysis
A.7.20 Validation

PART 4. Next steps

Part 4 proposes the next steps for future validation and modelling work.

A.7.21 Future validation
A.7.22 Future MyTh MaP-IN iterations and analysis

[24] The ODD+2D protocol (259) is the 2018 extension the original 2006 ODD protocol later updated in 2010 (166). The ODD protocol provides a standard for describing and sharing ABMs. In 2013 the first extension, the ODD+D protocol (137), added new questions on decision-making process. Then this 2018 extension, the ODD+2D protocol, added section on 'Input Data'. This protocol helps facilitate transparent, comprehendible, and consistent ABM dissemination so other modellers can more easily assess and reproduce the ABM.

Part 1. Model summary and team contributions

Model name – Myanmar-**Th**ailand **M**igr**a**tion **P**lanning & **I**ntermediary **N**etworks (MyTh MaP-IN)

Model type – agent-based model (ABM)

Model rules – heuristic IF-THEN rules, including some probabilistic rules

Empirical phenomenon – Low wage labour migration planning and execution in the Myanmar-Thailand corridor, including the social and intermediary network interactions that facilitate migration pathways and emergent levels of precarity.

Modelling team – The interdisciplinary team of researchers and modellers that contributed to this ABM include a computational social scientist, computer programmer, mathematical modeller, social epidemiologist, and behavioural and social scientist. This group collectively possesses a specialised set of technical, theoretical, and empirical knowledge to inform the MyTh MaP-IN ABM. The design and execution of the work was led and completed by Alys McAlpine (**AM**) as part of her Doctoral studies with technical and design contributions from Luke Demarest (**LD**) and advisory support from Dr Zaid Chalabi (**ZC**), Dr Ligia Kiss (**LK**), and Prof Cathy Zimmerman (**CZ**).

Team member contributions in brief: **AM** completed the data collection, ABM design, ABM analysis and write up; **LD** programmed the model and data visualisations; **ZC** reviewed the translation of the conceptual model and empirical analysis into model-based rules; **LK** and **CZ** reviewed the model assumptions and rules for domain accuracy.

Team member backgrounds and contributions in more detail:

1. **Lead Modeler –** Alys McAlpine is a Doctoral Candidate in the Public Health and Policy faculty at the London School of Hygiene and Tropical Medicine (LSHTM). She has spent her academic career studying the drivers of labour exploitation and gender-based violence (GBV) in migrant populations. During her doctorate, her training focused on computational social science and complex systems methodologies.

- **AM completed the following research activities for this ABM work:** research design; data collection and fieldwork management; data cleaning; empirical mixed-methods analysis to inform the ABM; development of the model conceptual framework; design of the model structure, entities, and rules; supervision of the model programmer's translation of the conceptual model and rules into the computational model; verification of the ABM sub-models; scenario analysis; sensitivity analysis; validation; and write up.

2. **Computer Programmer –** Luke Demarest is a computer programmer and computational artist. He is an Associate Lecturer in Graphic Communication Design at Central Saint Martins, University of the Arts London. He is proficient in creating interactive data visualizations and object-oriented simulations.
    - **LD made the following contributions to this ABM work:** programmed the digital participatory egocentric network tool that was used for data collection (242); programmed the network data visualization interfaces to inform the ABM parameters (242); contributed to the content and design of model documentation, figures, and tables; programmed the MyTh MaP-IN ABM; and supported on model verification steps.
3. **Mathematical modeller –** Dr Zaid Chalabi is an Honorary Associate Professor in Mathematical Modelling at University College London (UCL) and at LSHTM. He is an expert on the use of ABM and other mathematical modelling for complex systems research. Dr Chalabi was an essential member of AM's PhD Advisory Committee and the lead advisor for this ABM work.
    - **ZC advised and supported this ABM work in the following ways:** trained AM on ABM methods; directed AM's reading and scholarship on ABM; was the senior author on the corresponding ABM systematic review (254); instructed and reviewed AM's work developing the heuristic-based model rules; guided and quality checked AM and LD's translation of the conceptual model into the

computational model; guided AM on ABM methods of verification, validation, sensitivity analysis, and outcome analysis.

4. **Social epidemiologist & Migration and trafficking subject expert –** Dr Ligia Kiss is an Associate Professor in social epidemiology at UCL's Institute for Global Health and holds an honorary post at LSHTM. She is a domain expert on violence, human trafficking and health and has methodological expertise on the design and evaluation of complex interventions in a range of geographic regions. Dr Kiss is one of two Co-Supervisors for AM's PhD.
    - **LK advised on the ABM development, in the following ways**: guided AM's reading on complex systems theory and methods; gave valuable insights on the opportunity to use complex systems modelling for the migration and violence domain area; acted as the second reviewer and co-author on the corresponding ABM systematic review (254); reviewed the primary mixed-methods analysis and findings that inform the ABM; advised the empirical and theoretical underpinnings of the conceptual model during design and development; and reviewed the domain relevance of the key model entities identified for the scenario and sensitivity analysis.
5. **Behavioural and social scientist & Migration and trafficking subject expert–** Prof Cathy Zimmerman is a Professor in Migration, Violence and Health at LSHTM. She is a subject expert on violence, human trafficking, and health. She leads a global portfolio of applied research to inform evidence-based safe migration and trafficking prevention policy and practice. Prof Zimmerman is one of two Co-Supervisor for AM's PhD.
    - **CZ advised on the ABM development, in the following ways:** as a contributing author on the ABM systematic review (254); reviewed the primary mixed-methods analysis and findings that inform the ABM; advised the empirical and theoretical underpinnings of the conceptual model during design and development; and reviewed the domain relevance of the key model entities identified for the scenario and sensitivity analysis.

A.7.1 Purpose and audience

Purpose – This empirical-based ABM is an exploratory descriptive model (256) that contributes new conceptual knowledge of how low-wage labour migration pathways are planned and executed in highly irregular migration corridors, such as the Myanmar-Thailand corridor. The model aims to describe the complex migration pathways and emergent migration networks, and then offer a preliminary explanation about how individual levels of *hyper*-precarity emerge across different pathways.

This ABM is a tool and 'touchstone' for exploring, debating, and understanding the system of actors and range of actions and interactions that facilitate migration. There is currently a limited body of context-specific evidence that identifies migration mediation processes in highly irregular labour migration corridors or how these processes might influence labour migration outcomes (61, 74). This substantial research gap limits our understanding of the variety and complexity of migration experiences and outcomes. Understanding how migrants engage with labour migration systems is essential to explaining complex causal chains within these systems, which might be possible leverage points for intervention. This primarily descriptive ABM aims to be the first in a series of ABMs aiming to explain and predict the effectiveness of safe migration interventions (i.e., counterfactual scenario testing).

This empirically informed ABM models the Myanmar-Thailand migration corridor and is potentially relevant to other migration corridors between counties with highly porous borders and high rates of irregular migration (e.g., Cambodia-Thailand, Guatemala-Mexico, Mexico-USA, etc.).

Methodological contribution – In addition to the empirical purpose, a further aim of this ABM is to contribute methodological 'proof of concept' to advance the use of mixed-methods-informed ABMs for future intervention research. This work aims to advance the use of ABM to describe the complex, nonlinear, dynamic, and multi-level (hierarchical) systems, but

also explain causal mechanisms and test assumptions for intervention design. Agent-based modelling has not yet been used to inform, design, and test safer labour migration interventions (254) the way it has been used for other public health interventions, such as childhood obesity (300), vaccination strategies (301), controlling influenza pandemic (302), among others (147, 157). This computer simulation method offers a more feasible, less costly, and more ethical approach to intervention research that would be especially well suited to intervention development with hard-to-reach populations of migrants.

Model audience (or 'users') – This first descriptive ABM is designed for a wide audience of users situated at various levels of the labour migration system (e.g., practitioners, policy makers, donors, and other researchers). It is a tool for questioning, exploring, and understanding the relationship between migration decision making, networks, and pathways, as well as individual outcomes of precarity. This descriptive model can be used as a touchstone for debating controversial theories of change around 'regular' migration.

Examples of possible users and uses include:

Practitioners designing safe migration and anti-trafficking interventions can use this ABM as a tool to explore the full scope of the system for intervention opportunities and even test the sensitivity of the described system to certain parameter changes (e.g., locations of agency offices, change in Migrant's thresholds or motivations to migrate). Future iterations of this model could then be used to test interventions (i.e., counterfactuals).

Legislatures drafting migration and/or low wage labour policy can use this ABM to explore systems wide policy agendas. Future iterations could include new policy initiatives as an exogenous force on labour migration systems that may result in both foreseen and unforeseen changes in individuals' behaviours (i.e., agent adaptation).

Donors prioritizing how to invest finite resources can use this ABM to identify the range of system components to address and how these components relate to each other. Again, future iterations of this ABM could be used to identify promising leverage points in the system and to identify any barriers to intervention success that need to be addressed simultaneously (i.e., interaction of system elements).

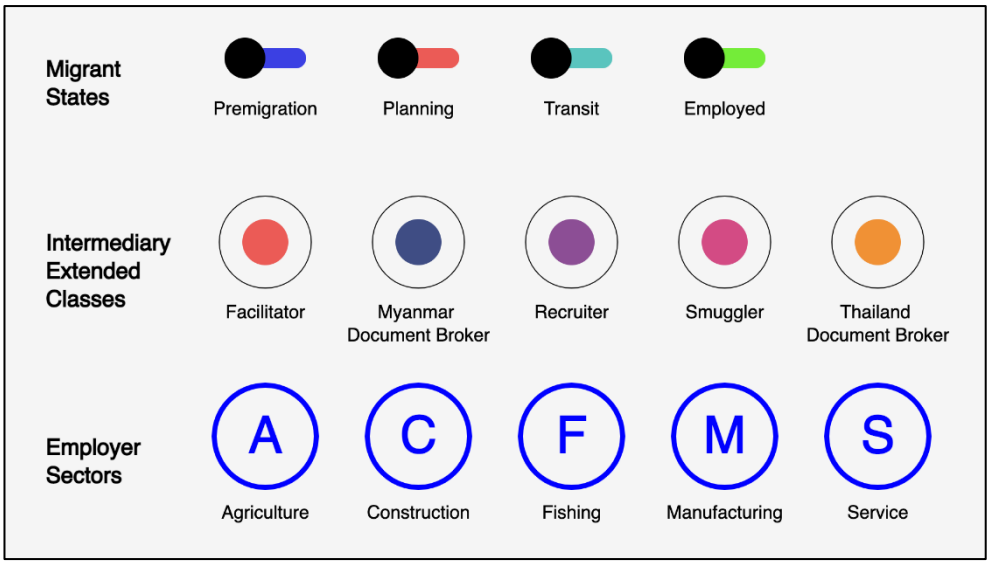
Researchers conducting safe migration intervention research can use this ABM to identify gaps in current understanding of how the system works to better inform future iterations of similar complex system models. This descriptive model, with thoughtful adaptations, can be used as the starting structure to build more explanatory and predictive ABMs.

A.7.2 Entities, properties, and scales

Model Entities – MyTh MaP-IN has three **agent entities** or 'classes' (*Migrant*, *Intermediary*, *Employer*) and three **environment entities** or 'areas' (origin, destination, border). The *Intermediary* class is divided further into five 'extended classes' (i.e., sub-groups of agents that inherit the parent class properties). Likewise, some of the environment entities have smaller 'sub-areas' or contain 'proto-agents' (*passport offices, agencies, crossings*).

Agent entities

Figure 26-A, repeated below from the main paper, details the visual features of the agent classes and sub-groupings (*Migrant* **states**, *Intermediary* **extended-classes**, *Employer* **sectors**).



Repeated Figure 26-A. Agent visuals by type and sub-group

N.B. Myanmar and Thai Document-Brokers look identical to signal their similar roles. They are distinguished by which side of the border they are on.

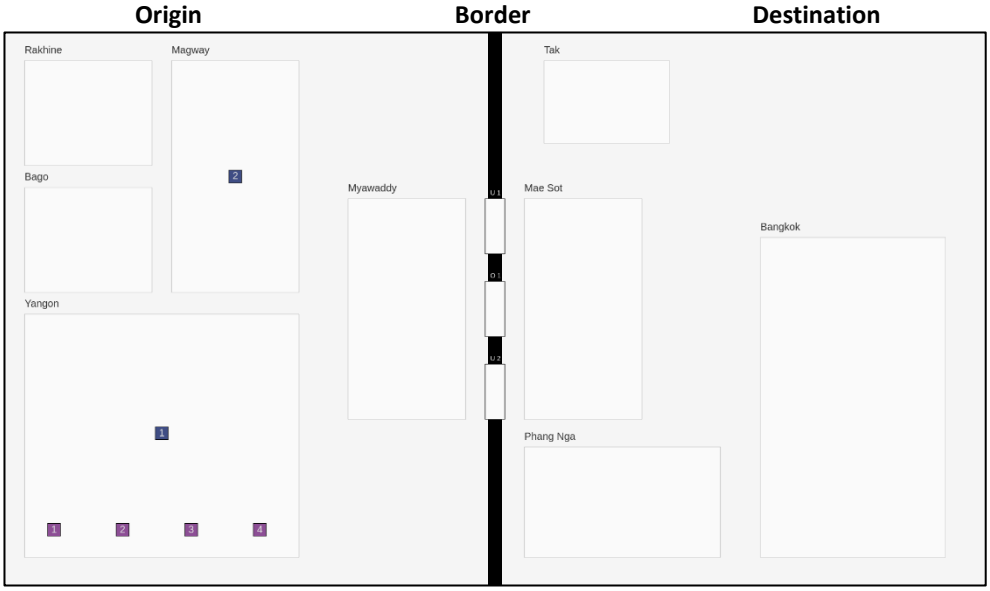
Agent classes, extended classes, and objects:

1. *Migrant* class – each instance contains a *migrations* array (size 0-many):
    i. *Migration* – each instance is a unique migration containing a *plan*:
        a. *plan* – group of properties describing intended *migration*
2. *Intermediary* class – five extension classes: Facilitator, Recruiter, Smuggler, Myanmar Document-Broker, and Thailand Document-Broker
3. *Employer* class – each instance is assigned to one of five work sectors: Agriculture, Construction, Fishing, Manufacturing, and Service

The properties, behaviours, and interactions that define the distinctions between these agent classes and extended classes are described in detail throughout this ODD+2D protocol.

Environment entities

Figure 26-B, repeated below, presents the environment (i.e., model space), which is an abstract representation of real geographic places of emigration and immigration in the Myanmar-Thailand migration corridor.



Repeated Figure 26-B. Environment without agents

Environment areas, sub-areas, proto-agents:

1. *Origin Area* (left side of Figure 26-B) with **five sub-areas**:
    - Two equal-sized rural: **Rakhine** and **Bago**
    - Three varying-sized urban, some with proto-agents:
        - **Magway** with one passport office ■
        - **Yangon** with one passport office ■ and four recruitment agencies ■■■■
        - **Myawaddy** - origin side of the border crossings
2. *Destination Area* (right side of Figure 26-B) with **four sub-areas**:
    - One rural: **Tak**
    - Three varying-sized urban: **Mae Sot** (destination side of the border crossings), **Phang Nga**, and **Bangkok**
3. Border with **three border crossings**:
    - One legal crossing:
        - **Official** – official immigration checkpoint
    - Two illegal crossings:
        - **Unofficial 1** – crossing without a Smuggler
        - **Unofficial 2** – crossing with a Smuggler

Figure 52 presents the model environment, but this time populated with the agents in their initialised locations (Initialisation described in Section A.7.15).

Note that when migrants move between locations or are connected to intermediaries during waiting stages (i.e., recruiters, smugglers, or employers) then the colour of the line showing the migrant's movement or connection represents which migration state they are in (Figure 52, middle and bottom images).

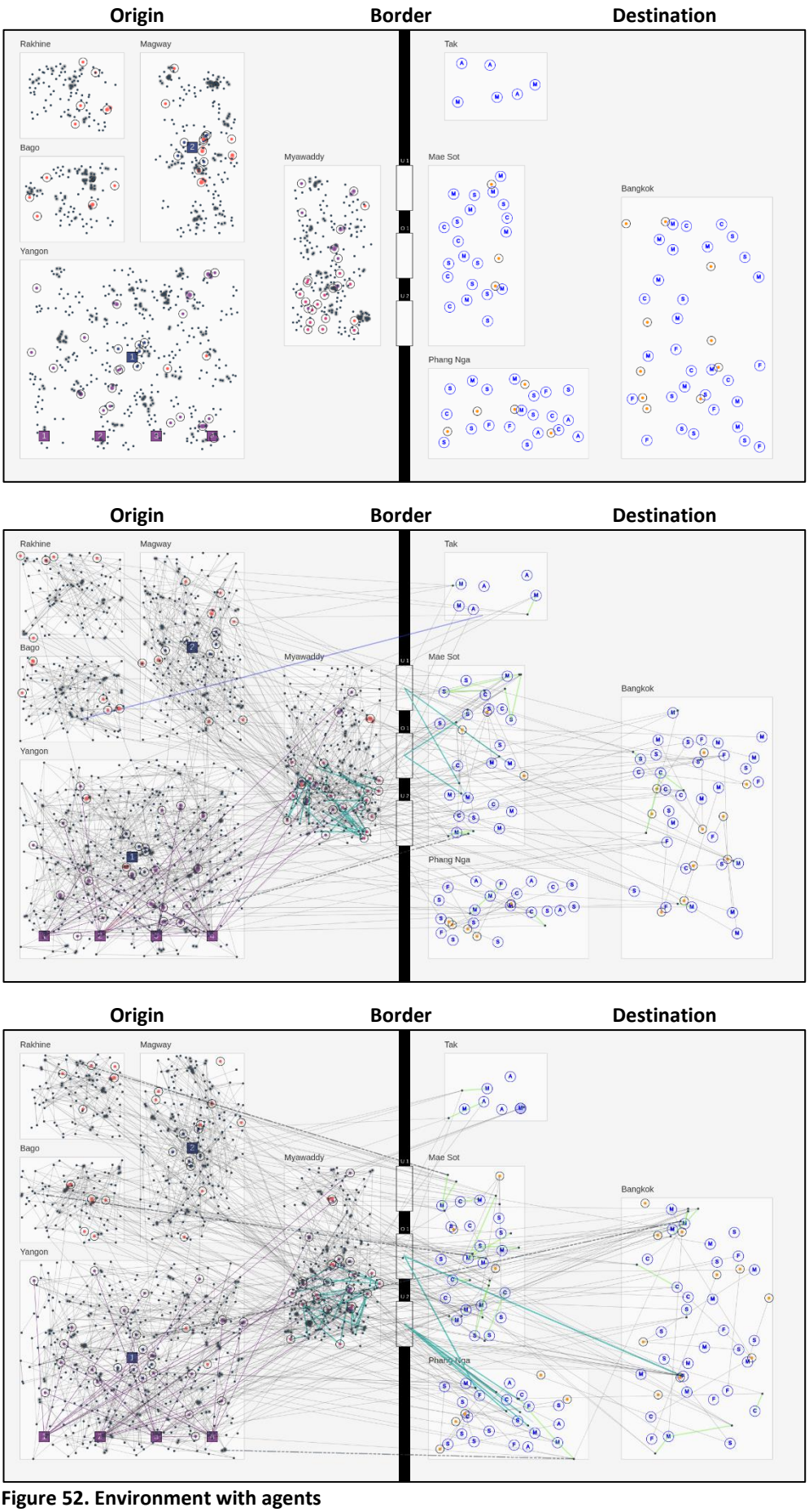


Figure 52. Environment with agents

Model attributes – All model entities have properties (i.e., state variables) and actions (i.e., behaviours, decisions, state changes). Figure 53 presents a Unified Modelling Language (UML)[25] diagram of the MyTh MaP-IN model structure: the entities, properties, and actions (or 'methods'). One important feature of the model structure is the modularity between an instance of a *Migrant* that contains zero to many instance(s) of a *Migration* that each have a respective *plan*. The separation of a *Migration* and its *plan* helps distinguish a *Migrant's* intentions from the actual migration experience, but the use of similar properties allows for comparison between the two (e.g., planned documentation vs. actual documentation). The UML diagram is not exhaustive of every property or action but covers most of them and all that are needed to understand the model process.

[25] UML is a standard graphical visualization for software development that is independent from any specific programming language or computer platform. Complex system simulations built using object oriented (OO) programming can be easily presented in the UML class diagram format, which includes relationships between classes such as *association* and *inheritance*). The format is intuitive and has a relatively low technical barrier (compared to writing code) and thus can be easily implemented and comprehended by a range of modellers. UML diagrams are a useful tool to summarise an ABM and it is argued that it can encourage greater focus on the modelling before the coding, yet it is still rarely included in ABM documentation (303).

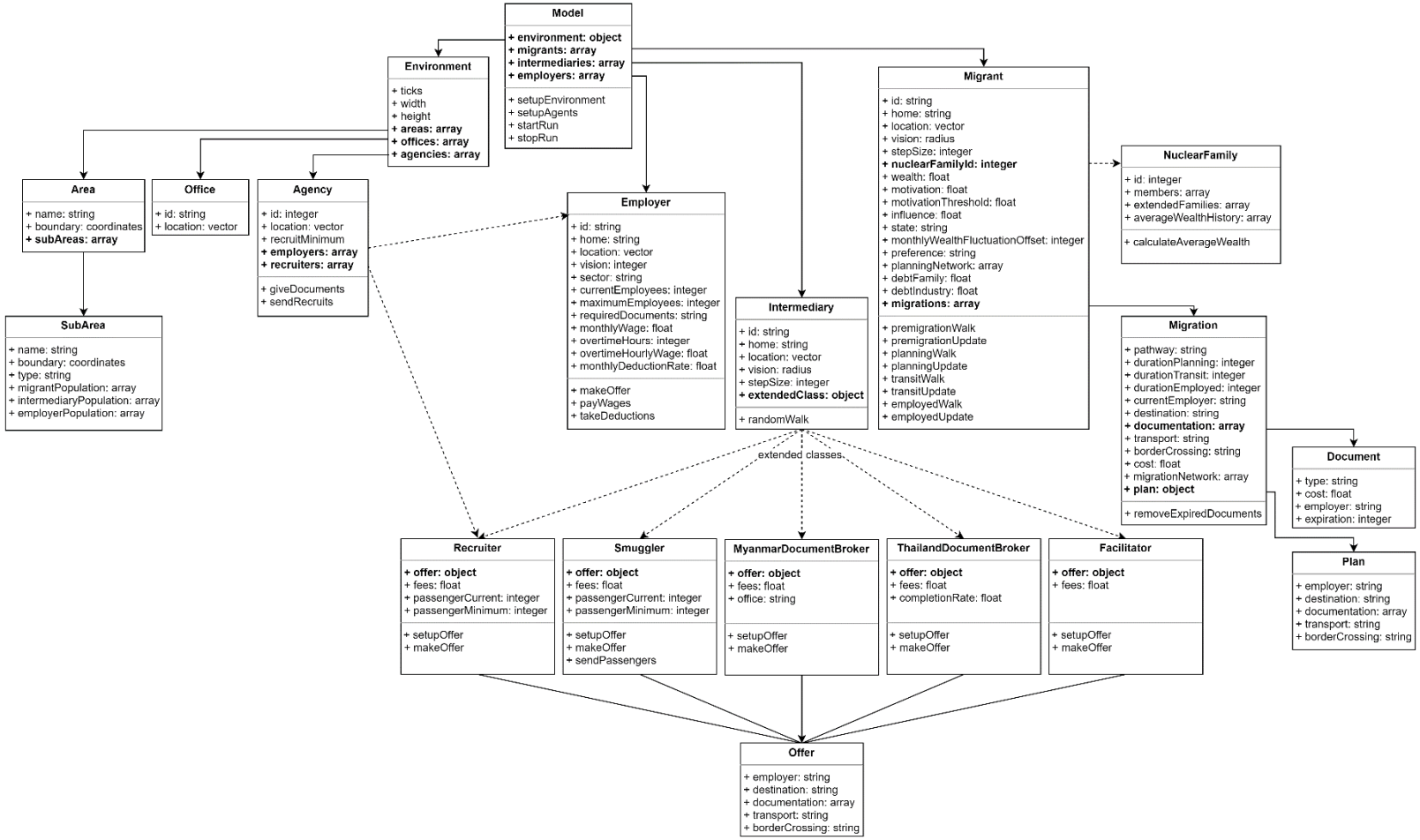


Figure 53. MyTh MaP-IN UML diagram

Model attributes (continued) – Table 41 lists the agent properties**,** their data structure, possible value, initialised value, and static or dynamic nature.

Table 41. Agent properties

	property	data type[1]	possible value	Initialised value	
All Classes	id	string	unique character/number string	**Migrant**: m0 . . .mN, **Intermediary**: i0 . . .iN, **Employer**: e0 . . .eN	S
	home	string	one of origin or destination sub-area	randomly allocated to match predetermined distributions from config file	S
	location	vector	x, y	randomly located within **home** sub-area. Two **agent class** conditions: **Employers** cannot overlap with each other; **Myanmar-Doc-Brokers** stay within a radius around passport offices.	D
	vision (and expanded vision)	radius	node diameter*X (and node diameter*X)	fixed radius around agent node (location specific)	S
	stepSize	integer	?	depends on agent class/state – move to each agent section below?	S
Migrant	nuclearFamilyId	integer	1+	randomly assigned and each id can be assigned to 1-5 Migrants	S
	extendedFamilies	array	0-2 nuclear family ids	1-3 nuclear family ids in same **home** area are randomly put into an extended family grouping	S
	wealth	float	constrained to 0-1 at end of every time-step	random within **home** specific ranges: rural (0 - 0.03), urban (0.015 - 0.045) (260)	D
	motivation	float	0 - 0.99	random between 0 - 0.35	D
	motivationThreshold	float	0.7 - 1	random between 0.7 - 1	S
	influence	float	0-1	random between 0 - 1	D
	state	string	'pre-migration', 'planning', 'transit', 'employed'	pre-migration	D
	monthlyWealthFluctuationOffset	integer	1-30	random between 1-30	S
	preference	string	one of eight preference types	randomly assigned (See additional description of **Preference** property and distributions on next page.)	S
	planningNetwork	array	id(s) of Migrants and Intermediaries	empty	D
	debtFamily	float	0+ (no max)	0	D
	debtIndustry	float	0+ (no max)	0	D
	migrations	array	**Migration** instance(s)	empty (See **Migration** class below.)	D
Migration	durationPlanning	integer	0+	0	D
	durationTransit	integer	0+	0	D
	durationEmployed	integer	0+	0	D
	migrationNetwork	array	id(s) of Migrants, Intermediaries, and Employers	empty	D
	destination	string	one of destination sub-areas	empty	D

	borderCrossing	string	'official', 'unofficial1', 'unofficial2'	empty	D
	currentEmployer	string	employer id	empty	D
	cost	float	0+ (no max)	0	D
	plan	object	**Plan** instance	empty (See **Plan** class below.)	D
	documentation	array	**Document** instance(s)	empty (See **Document** class below.)	D
Plan	employer	string	employer id	empty	D
Plan	destination	string	one of destination sub-areas	empty	D
Plan	documentation	array	'border pass', 'work permit', 'passport', 'none'	empty	D
Plan	transport	string	smuggler's id, recruiter id, migrant id	empty	D
Plan	borderCrossing	string	'official', 'unofficial1', 'unofficial2'	empty	D
Document	type	string	'border pass', 'work permit', 'passport'	context specific generation based off interactions	S
Document	cost	float	.001 - .025 (100 – 2,500 THB)	assigned based on **type**: border pass = .001, work permit = .018, passport in Myanmar = .02, work permit in Thailand = .025, temporary passport in Thailand: 0.01	S
Document	expiration	integer	7 - 1825	assigned based on **type**: **border pass =** random between 7-1825**, work permit =** 730, **passport =** 1825, **temporary passport** = 730	S
Document	employer	string	employer id	empty	S
Agency	id	integer	1, 2, 3, 4	four agencies are initialised with unique 1-4 ids	S
Agency	employers	array	employer id(s)	randomly assign 5 unique Employers that have requiredDocumentation = 'work permit'	S
Agency	recruiters	array	recruiter id(s)	randomly assigned, at least one Recruiter in Yangon and one in Myawaddy per agency	S
Agency	recruitMinimum (per employer)	integer	3	**Recruiter** only: 3 for each employer in roster	S
Intermediary[2]	extended class	string	one of the five Intermediary types	randomly allocated to match predetermined distributions	S
Intermediary[2]	links	array	id(s) of Intermediaries and Employers	randomly created based on predetermined link probabilities	S
Intermediary[2]	fees	float	0.005 - 0.30 (500-30,000 THB)	randomly assigned within **extended class** ranges: **Recruiter** (0.05-0.30); **Facilitator** (0.02-0.15); **Smuggler** (0.05-0.10); **Myanmar-Doc-Broker** (0.02-0.04); **Thai-Doc-Broker** (0.04-0.10)	S
Intermediary[2]	agency	integer	1, 2, 3, 4	randomly assigned to **Recruiters** only	S
Intermediary[2]	passengerCurrent	integer	0+	**Smuggler** only: 0	D
Intermediary[2]	completionRate	float	.5-1	**Thai-Doc-Broker** only: randomly assigned	S

	passengerMinimum	integer	4-6	**Smuggler** only: randomly assigned between 4-6	S
	offer	object	**Offer** instance	empty (See **Offer** class below.)	-
Offer	employer	string	employer id	See Section A.7.9 for a description of **offer properties** for each **Intermediary extended class.** Offers contain a combination of the five offer properties listed here. The offer property values are assigned at initialisation unless described otherwise. Whether the properties are static, or dynamic depends partly on the **extended class**.	
	destination	string	one of four destination sub-areas		
	documentation	array	'border pass', 'work permit', 'passport', 'none'		
	transport	string	smuggler's id, recruiter id, migrant id		
	borderCrossing	string	'official', 'unofficial1', 'unofficial2'		
Employer	sector	string	one of five sectors	randomly allocated to match predetermined distributions	S
	currentEmployees	integer	0+	0	D
	maximumEmployees	integer	0+	by **sector**: **Agriculture** & **Services** (15); **Manufacturing** (100)**; Construction** (50); **Fishing** (30)	S
	requiredDocuments	string	'passport', 'work permit' with employer id, 'none'	by **sector**: **Agriculture** & **Services:** 'none required'; **Manufacturing, Fishing,** & **Construction:** random assigned 25% 'passport', 25% 'work permit' with employer's id', 50% 'none required'	S
	monthlyWage	float	0.0-.10 (0 – 10,000 THB)	randomly assigned within **sector** ranges: **Agriculture** & **Services** (.0-.08); **Manufacturing, Fishing,** & **Construction** (.0-.10)	S
	overtimeHours	integer	0-320	random between 0-320	S
	overtimeHourlyWage	float	0.000-0.004 (0-400 THB)	random between 0.000-0.004	S
	monthlyDeductionRate	float	0-0.5	random between 0-0.5	S
	links	array	id(s) of Thai-Document-Brokers	randomly allocated to match predetermined distributions	S

[1] Data structure key: integer = integer variable; float = real variable; string = categorical variable; array = list; object = model entity with its own set of properties with their own data structures

[2] For succinctness, all possible Intermediary properties are listed together, but the UML diagram depicts how each Intermediary extended class (e.g., Recruiter*)* has a unique set of properties.

Model attributes (continued) – This section provides additional details on select model attributes described in Table 41, including: currency, wealth, and migration preferences.

Currency: All the financial attributes of the model (e.g., wealth, fees, wages) represent Thai Baht (THB) currencies and are formalised as a float (i.e., a decimal). Financial attributes, as well as most other model attributes, adhere to a 0-1 range (i.e., normalised) for ease of interpretation and to allow convenient mapping to other ranges. The value range for financial attributes are informed by empirical data. Any empirical values that are stated in Myanmar Kyat (MMK) currency (e.g., pre-migration wealth) have been converted into THB using a 2019 exchange rate[26].

Currency translation examples (THB multiplied by 10^{-5} = empirical currency):

- 0.00001 = 1 THB (equivalent to approximately 47 MMK or $0.03 USD)
- 0.0033 = 330 THB (legal minimum daily wage in Thailand)
- 0.5 = 50,000 THB (approximate 6-month legal minimum wage)
- 1.0 = 100,000 THB (equivalent to approximately 4,723,580 MMK or $3,080.92 USD)

Wealth: Migrant wealth is a dynamic property. At the end of every time-step, wealth is constrained to 0 - 1, but during the time-step wealth might exceed these bounds temporarily depending on interactions or behaviours.

Preference: A Migrant agent has a migration 'preference' that influences their decision-making (Table 42). More research is needed to inform more sophisticated cognitive models of how preferences may interact, change over time, adapt to different contexts, but preferences in this model represent heterogeneous individual migration decision-making.

[26] Currency conversions were calculate using the Oanda currency converter for 1 January 2019, the year of data collection for this study. (www1.oanda.com/currency/converter/)

Table 42. Migrant preferences

Migrant preferences (in model)	Baseline distributions	CHIME study (81) and MMSNA study (215) findings
1. **Social** – community at destination: **destination** population has highest number of *Migrant* agents from **home**	**15%**	Friends at destination (30%)
2. **Family** – vetted pathways by family: **offer** from a family member	**15%**	Family/relatives at destination (16%)
3. **Intermediary –** wanting help/services: **offer** from *any* intermediary	**15%**	Availability of brokers/recruiters able to arrange migration (25%)
4. **Work** – plan for employer: **offer** includes employer	**15%**	Confidence in finding employment at destination (12%), Work arranged prior to migration (7%)
5. **Sector – '**comfortable'/indoor work: **sector** = manufacturing OR services	**15%**	-Not included in CHIME- Came up as a very common theme in the MMSNA qualitative findings.
6. **Wage –** 'high' wage: **monthlyWage** ≥ .09 (i.e., 9,000 THB for 1-months work)	**10%**	Highest potential income option (7%)
7. **Fees –** 'cheapest' pathway: lowest total **fees**	**5%**	Low cost of migrating to destination. (2%)
8. **Proximity –** near home/'easy' to get to: **destination** closest to **home**	**5%**	Proximity of destination to home. (1%)
9. **Legal –** documented migration: **documentation** includes 'passport' **or** 'work permit'	**5%**	-Not included in CHIME- Came up as a common theme in the MMSNA qualitative findings.

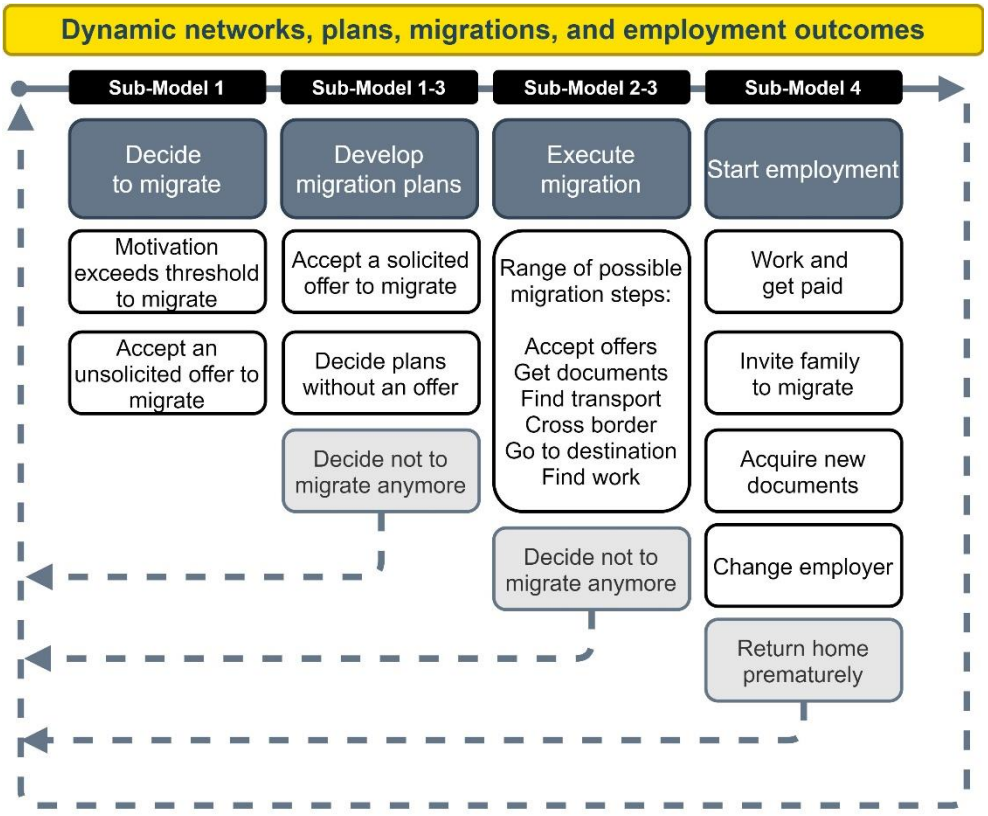
Exogenous factors. Some of the model attributes and drivers are initialised at set values and are thus exogenous to the model. For example, the time it takes to process a passport and/or work permit, the distance between environment areas and time it takes to traverse them the daily cost of transit, debt interest rates, and debt deduction rates. These exogenous factors are described as global parameters in Section A.7.17.

Temporality – The *time-steps* (i.e., 'ticks') in the model represent days. The model *time-horizon* (i.e., model 'run' length) is 1,825 *time-steps* (5-years). The model run 'stops' when the completed time-steps reach the time-horizon. The 5-year time-horizon was chosen for a few reasons:

1. MyTh MaP-IN is informed by empirical data that was collected in 2019 from individuals that migrated to Thailand within the past 5-years (to minimise recall bias). This model is describing those migrations that took place between 2014-2019.
2. Additionally, beyond 5-years, most individuals will go through some significant life events (e.g., get married, have a baby, age out of work) that can alter their migration decision-making. A longer migrant life course approach is not central to the research questions and thus outside the scope of this ABM.
3. Finally, and practically, a 5-year time-horizon was achievable within the computational power available for this thesis research. However, 5-year runs still allowed for the possibility of 'repeat' migrations in a single run (i.e., seeing how a Migrant might adapt their behaviours across migrations) given that the average migration from Myanmar to Thailand lasts between 2-3 years (82).

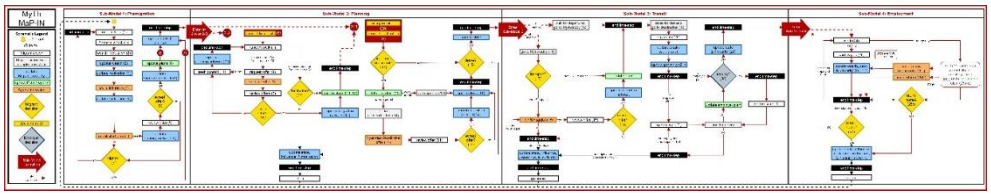
A.7.3 Process overview

MyTh MaP-IN consists of four sub-model processes. *Migrant* agents sequentially navigate through the sub-model processes to achieve two overall goals: 1) migrate to a chosen destination; and 2) be employed. A *Migrant* must first decide to migrate before they start forming plans to migrate. Planning and executing a migration involves a series of decisions, but also interactions with other *Migrant*, *Intermediary*, and, if they arrive at destination, *Employer* agents. See Figure 27, repeated below, for a high-level conceptual framework of the overall model from the perspective of a *Migrant*. The actions that a Migrant takes to both develop and execute migration, respectively, may occur in stages over multiple sub-models. The black boxes in Figure 27 note all the possible sub-models that include any possible steps in these processes, the grey boxes summarise the step in the migration process, and the white boxes give examples of the types of agent behaviours in that migration step.



Repeated Figure 27. High-level conceptual model

The conceptual framework in Figure 27 guided the development of the sub-model rules and schedule. Figure 32, repeated below, is a schematic that details *Migrant* agents' behaviours, decisions, and interactions. Section A.7.17 presents each sub-model and its respective rules, but Figure 32 has been included here to illustrate the translation of the high-level conceptual model into computational processes and rules.



Repeated Figure 32. MyTh MaP-IN model schematic

A.7.4 Theoretical and empirical background

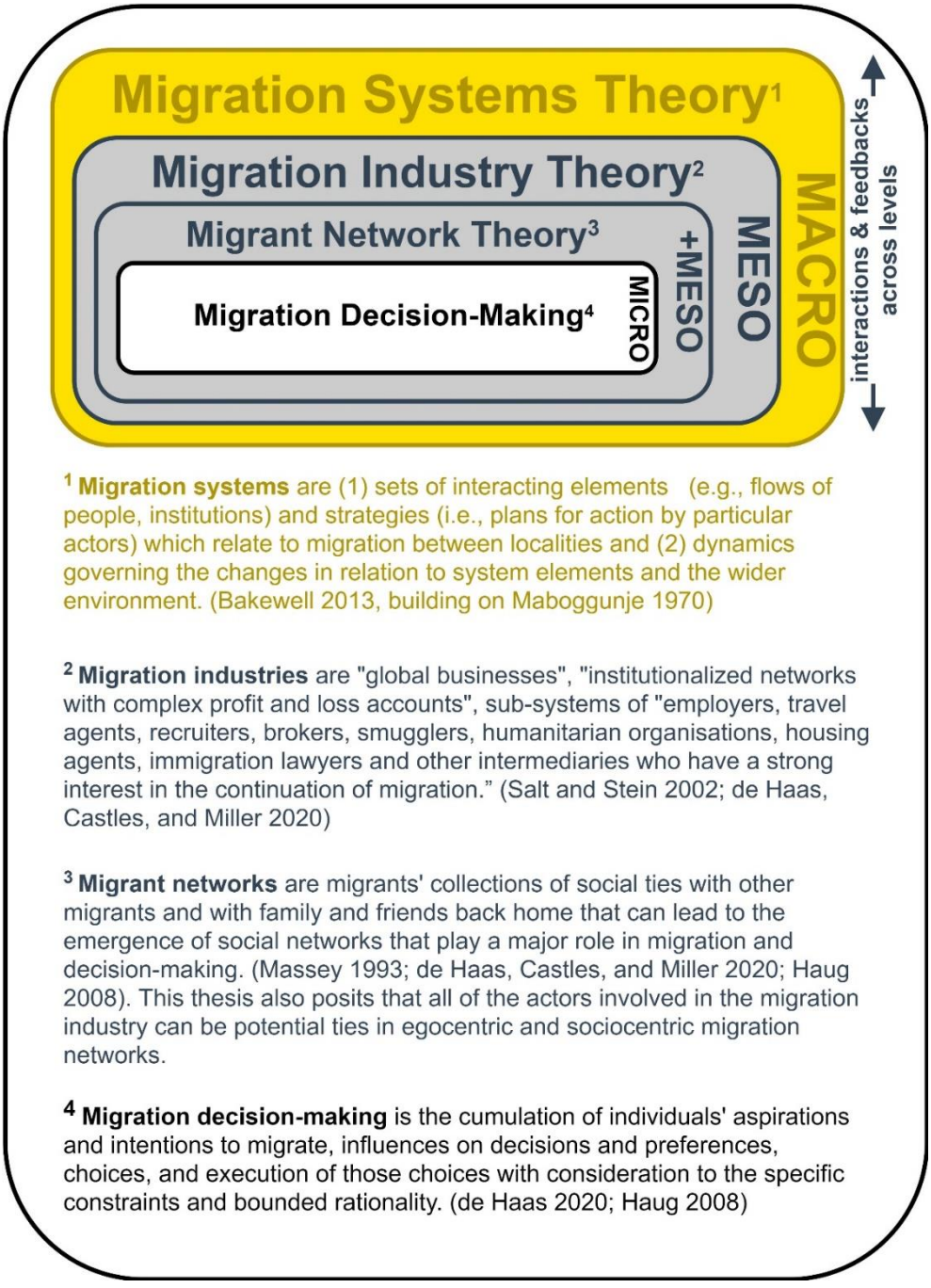
Massey and his contemporaries, Caroline Brettell and James Hollifield, suggest that interdisciplinary migration research creates an opportunity to use conceptual tools at different levels of analysis (e.g., micro-meso-macro) – a suggestion that is highly compatible to a complex realist approach (105, 106). In the aim of producing a multi-level model that captures some of the complexity of the Myanmar-Thailand migration corridor, this model is informed by a complimentary blend of theory and empirical evidence addressing the macro, meso and micro level entities, rules, and interactions.

The information and data that inform the MyTh MaP-IN model include:

- multi-level migration domain knowledge and theory (A.7.4a);
- published research on Myanmar-Thailand migration (A.7.4b); and
- empirical mixed-methods social network analysis (MMSNA) using data collected to inform the MyTh MaP-IN ABM (A.7.4c).

A.7.4a Multi-level migration theories

Figure 4, repeated below, summarises the **multi-level migration system theoretical framework** that informed the MyTH MaP-IN ABM. The framework depicts multiple levels of migration theory (micro-meso-macro) and an arrow representing inter-level interactions and feedbacks across the levels which make the content of each level change and adapt over time.



Repeated Figure 4. Multi-level migration system theoretical framework

Macro theory – informed choice of method and model entities

Senior Migration and Development Lecturer Oliver Bakewell, proposes a reformulated migration system theory (107) building on Mabogunje's similar work in 1970 (108). Bakewell defines a migration system as one that has:

> "(1) a set of interacting elements—including flows of people, ideas and goods, institutions . . . and strategies as in plans for action by particular actors—which relate to the migration between localities; and
>
> (2) dynamics governing the way in which the elements change in relation to changes in both these system elements (feedback mechanisms) and in the wider environment." (107, p. 310)

This theory supports the case for using complex systems methodologies that can feasibly explore system interactions and dynamics. Bakewell's definition suggests possible system features ('interacting elements', 'strategies', 'dynamics', 'feedbacks', 'environment') to incorporate into future conceptual or empirical work that addresses migration systems. This theory also guided the conceptual framework and empirical data collection for this ABM to ensure we addressed the "interacting elements" (e.g., people moving between environments, financial transactions, information exchanges) and the "dynamics governing" the processes and interactions within the system and impacting system elements.

Meso level theory – informed agent-agent and -environment interactions

Renowned migration scholars, Hein de Haas, Stephen Castles, and Mark Miller, state that a 'migration industry' can consist of, "employers, travel agents, recruiters, brokers, smugglers, humanitarian organisations, housing agents, immigration lawyers and other intermediaries who have a strong interest in the continuation of migration." (109, p. 66) John Salt and Jeremy Stein describe migration as, "a global business which has both legitimate and illegitimate sides . . . a system of institutionalised networks with complex profit and loss." (110, p. 22)

Bakewell, Castles, and Salt and Stein's complimentary theories informed our thinking of migration as a 'system of systems'. For example, a global system of entities and flows that encompasses smaller finite sub-systems that sustain the dynamics and trends at all levels, such as industrial sectors that systematically recruit foreign workforces or social networks that sustain flows in specific corridors.

De Haas, Castles and Miller also explain that migrants "create and maintain social ties with other migrants and with family and friends back home . . .this can lead to the emergence of social networks (meso level structures)." (109, p. 65) Sonja Haug's work adds to the discussion on migration networks, she explains, "theoretical models and fragments of empirical evidence in several fields, show that migration networks play a major role in migration [and decision-making]." (60)

Castles suggests that migration theory and methods should be "able to incorporate both structure [macro-social] and agency [micro-social]." (119) That is, to address the larger 'system', such as geographies of migration or international immigration policy, while also acknowledging individual acts of agency, such as migration decision-making or work preference. Meso-level theories, such as migration industry theory and migration network theory, provide frameworks to consider potential 'touchpoints' between structure and agency. For example, social networks that emerge from individual migration choices and in turn establish macro level migration corridors. These corridors trends often influence immigration policy that then feeds back into the networks of decision-makers. The migration system encompasses individual actions and structural forces, but also the emergent properties of meso-level sub-systems and networks. To this point, we have considered the social and intermediary networks at the meso-level of the Migration-Thailand migration system.

Intermediaries (e.g., brokers, recruiters, 'middlemen') are a key group of actors that form specific migration industries within the system. An emerging body of research on migration intermediaries (61), highlights the range of roles they execute in the migration system and the way they are

embedded within most migration processes. Dovelyn Agunias, an expert on migration mediation in many contexts, explains,

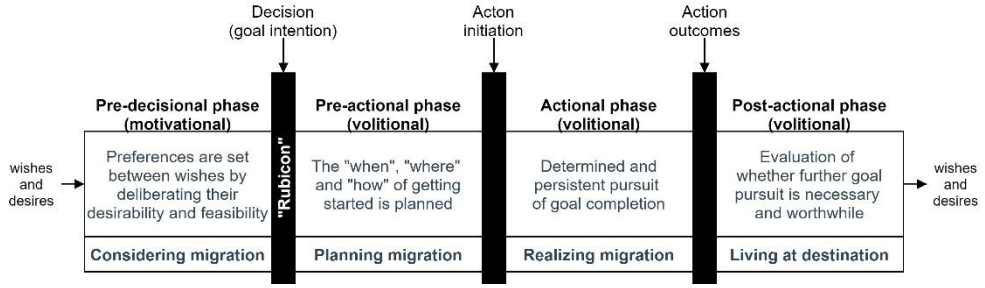
> By providing information and extending critical services in many stages of migration . . . legitimate intermediaries build migrants' capabilities and expand their range of choice. In the best of cases, intermediaries allow migrants the opportunity to move and pursue a life of meaning — the very essence of human development. . . . However, the services intermediaries provide come at a cost. It is difficult to draw a clear line between a reasonable fee for valuable services and exploitative charges or practices, or between exploitation and criminal abuse. (Agunias, 2009: 2) (304, p. 2)

Social networks are also a key meso-level sub-system that play a direct role in facilitating migration process. To date, the majority of research on migration networks has focused on these social networks (i.e., social groups of migrants facilitating flows) and some research, but minimal theoretical work, on intermediary networks, such as smugglers (64), and even less on the interaction or overlap of these social and intermediary networks (or 'industries'). The empirical data collection and analysis probed at these different actor groups and how these actors' relationships and interactions formed mixed intermediary and social networks at the meso-level of the migration system.

Micro level theory – informed agent behaviours, decisions, and processes

A single theory would struggle to explain all possible micro-behaviours exhibited by actors in a migration system. The micro-level of this multi-level theoretical framework focuses on migration decision-making as a key micro-influence on individual migration processes, the empirical focus of this thesis. Individual migrations are often conceptualised as trajectories (or 'pathways'). Stefanie Kley, sociologist and economist, adapted the Rubicon model of 'action phases' to the behavioural stages of migration (Figure 5, repeated below) (114). Kley's model depicts four migration stages isolated by decision or action points. The stages include considering ('pre-decisional'), planning ('pre-actional'), and realizing ('actional') migration, and living at destination ('post-actional'). Zimmerman, Kiss, and Hossain,

also consider migration ‘stages’ as a way to conceptualise the typical actions, opportunities, or vulnerabilities at various points in migration (5). Framing migration ‘pathways’ by stages offers one way to explore and organise the range of decision-making and decision-making consequences that take place across the full trajectory of a migration. The MyTh MaP-IN sub-model represent the different migration stages discussed in the literature and incorporates specific opportunities, interactions, and decisions that are typical to specific locations and/or stages of a migration ‘pathway’.



Repeated Figure 5. Kley’s Rubicon model of planned action for migration (114)

Hein de Haas argues that “the main conceptual problem of conventional theoretical accounts of migration remains their inability to meaningfully conceptualise how individual migrants and groups of migrants exert agency within broader structural constraints.”(115, p. 14) De Haas offers a theory to bridge the agency versus structure debate (micro vs. macro) with key relevance to migration decision-making (ibid). De Hass’s ‘aspiration-capabilities framework’ conceptualises migration as, “a function of people’s capabilities and aspirations to migrate within given sets of perceived geographical opportunity structures.” (115, p. 2) That is, migrants’ decisions to act, regardless of the motivation to migrate, are restricted by what is feasible given the broader meso- and macro- realities. Informed by de Haas’s framework, the MyTh MaP-IN model formalises migrants’ aspirations (to migrate, to find work, to satisfy individual preferences) within a system of opportunities, constraints, barriers, and possible failures (or drop outs) and the decisions to migrate being a function of both these agencies and capabilities (109). Not excluding that migrants, at times, can have the agency to defy structural constraints (e.g., poverty, oppression, migration restrictions) (115).

There is not a singular theory for migration decision-making, but the literature provides some general insights on migration decision-making that have informed some of the rules in this model, in addition to the Aspirations-Capabilities Framework. These individual decision models are situated within and interact with the larger networks, industries, and migration system, these include the following migrant decision-making assumptions:

While there is not yet a robust theory on migration decision-making, empirical research provides preliminary insights on this individualised process, including:

- economic incentives explain some but not all motivations to migrate (60);
- the decision to migrate is often a household, not individual, decision (The New Economics of Labour Migration Theory) (109);
- migration decisions are made under a range of uncertainties, with imperfect and incomplete information (116);
- migration is a 'complex choice' with multiple objects and subjects of decision making at different stages (117); and
- the decision to migrate irregularly is often a means to circumvent unfavourable state systems, but also an emergent property of entrepreneurial initiatives within migrant networks (118).

The MyTh MaP-IN model builds on a strong body of interdisciplinary and multi-level migration theory. The model structure and global parameters formalise the geographical corridor and immigration policies that dynamically generate Myanmar-Thailand migration flows, as well as the industries and mixed social and intermediary networks that influence and facilitate migration pathways in the system. The actors within these migration networks execute their agency in the way they interact and make decisions across the stages of their migration process. The specifics of the entities and rules that govern this multi-level model are informed by a body of empirical research in the Myanmar-Thailand corridor.

A.7.4b Published research on Myanmar-Thailand migration

MyTh MaP-IN references the findings from two recent empirical studies to inform some of the model rules:

- In 2017, **University of Sussex** researchers and the **International Organisation for Migration** (IOM) conducted a mixed-methods study, *Capitalising Human Mobility for Poverty Alleviation and Inclusive Development in Myanmar,* that collected data on Myanmar migration trends in a randomly sampled household survey (n = 3,116) and qualitative interviews (n=192). This study aimed to "to address the lack of research regarding migration and its impacts on development in Myanmar . . . to generate evidence on contemporary labour migration patterns and impacts at the individual, household and community levels." (81) Hereafter referred to as 'the CHIIME study'
- In 2020, the **Central Statistical Organization** (CSO), **United Nations Development Programme** (UNDP), and **World Bank** co-produced the *Myanmar Living Conditions Survey 2017: Socio-economic Report*, which presents the findings from a large-scale multi-topic nationally representative living conditions survey (n = 13,730). (260) Hereafter referred to as 'the MLC survey'.

A.7.4c Empirical research on Myanmar-Thailand migration

The primary evidence that inform the MyTh MaP-IN rules is the empirical analysis that A. McAlpine completed as part of her thesis work. McAlpine conducted interviews with migrant workers in Thailand. These interviews included participatory egocentric network mapping, demographic and outcome survey questions, and in-depth qualitative probing. This data was analysed using a mixed-methods social network analysis (MMSNA) approach and the findings of this empirical analysis have been written up as a separate paper as part of A. McAlpine's doctoral thesis (215). Hereafter referred to as 'the MMSNA study'.

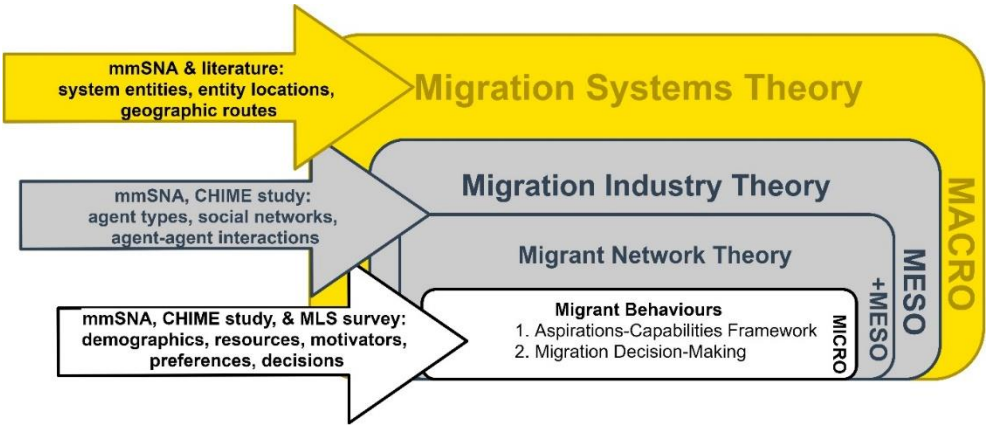
Empirical data – The empirical data for the MMSNA study was collected in 2019 in three data collection sites in Thailand: Phang Nga region, Tak region (including Mae Sot central); and Mahachai region (outside of Bangkok). The sample is Myanmar adults (18 years or older) that are living in Thailand and migrated to Thailand for work in the last 5 years. The total sample size was n=100 but only 81 of the interviews were used for the empirical analysis (4 interviews were excluded based on sampling criteria, 15 interviews were

randomly partitioned for model rule validation – see Section A.7.20). The dataset includes both quantitative and qualitative data that were collected during single interview sessions. The structured quantitative dataset includes egocentric network data (both egos and alters), demographic attributes of both egos and alters, and various work and migration outcomes. The qualitative dataset is made up of interview transcripts where migrants described their migration narratives in more detail including their relationships and exchanges with the alters in their migration networks. More details on the methods of data collection and analysis can be found in the MMSNA paper (215).

Data aggregation – The data is available at the individual and egocentric network level (i.e., migrant interviewees and the network of people they described as being involved in their migration).

Combining the model inputs

Figure 28, repeated below, presents a high-level outline of how the published research and empirical analysis informed the different levels of the MyTh MaP-IN model. The multi-level migration theories (squares) and data sources (arrows) were triangulated in the model design process.



Repeated Figure 28. Theory and evidence informing the MyTh MaP-IN model

Model assumptions

A summary of some of the key assumptions that informed the model design are bulleted in thematic groupings.

Assumptions about pre-migration and the motivation to migrate

- All migrant agents have wealth that fluctuates over time on the assumption that all family members, regardless of working age, have household wealth allocated to their livelihood. Unemployment is not explicitly formalised but is one type of financial loss modelled as a simple 'financial shock' catch-all.
- On average, *pre-migration* wealth decreases over time due to possible financial shocks.
- Motivation to migrate is heterogeneous and is affected by social influences and relative (not absolute) nuclear family wealth.
    - Social influence from family members and returned migrants is double weighted.
    - Positive and negative influences that are the same relevant distance from an agent's current motivation have the same proportional effect on motivation.
    - Relative wealth influences all migrants' motivation uniformly.
    - The relative poorest and highest wealth brackets are less incentives to migrate compared to low-middle range family wealth categories.
    - All agents are aware of the wealth and influence of migrants in their home area and/or vision.
    - Social influence affects all agents' motivation, but wealth only affects agents with motivation below a certain value.
- Some agents have a migration threshold set so that they can never migrate based on the assumption that some population members would never migrate due to health or age.
- Agents with a certain level of motivation to migrate are more susceptible to accepting offers to migrate than individuals with relatively low motivation (compared to individual thresholds to migrate).

Assumptions about the Migrant decisions

- Migrants only receive social offers (i.e., not intermediary offers) to migrate from family members and are more likely to accept family offers than intermediaries offers at the 'decision to migrate' stage (i.e., before they are proactively looking for any plans).
- Migrants have individual preferences that guide their migration choices.

- Migrants without any plans to migrate will seek out advice or help from contacts they know or know of. Eventually, migrants that do not receive help will make independent migration decisions.
- Migration plans can be discontinued at any stage of migration.
- Destination plans affect migrants' documentation and transport decisions. Documentation decisions affect migrants' transportation decisions.
- If a migrant has accepted an offer from a Recruiter or already has a passport then they are less likely to decide to discontinue their migration after these offers or exchanges have taken place

Assumptions about Intermediaries

- Different types of intermediaries are in certain areas which influences which offers an individual might receive or have access to. Migrants know the location of smugglers in Myawaddy.
- Migrants that use Myanmar-Doc-Brokers or Recruiters are guaranteed to receive their documentation pre-migration.
- Not all intermediaries link equally to all other intermediaries and not all intermediary links are bidirectional.
- Smuggler and recruiter intermediaries work on 'economies of scale' which means they must meet minimum numbers of migrant customers to move a group of migrants onto the next stage of migration.

Assumptions about migrations and employment

- Migration pathways are established and sustained by migration networks, especially family inviting other family.
- All Migrants that decide to leave home are either able to cover the costs of migration from their individual wealth or are willing to execute migrations by taking on debt to social networks or to the migration industry (i.e., intermediaries, employers).
- Migrants can leave home without a full migration plan.
- Migration is pathway dependent, and decisions made in one time-step will increase or decrease the likelihood of future decision outcomes.
- Passport costs the same regardless of the passport office location.
- All Migrants can acquire a border pass if they pass through the official border crossing.
- Migration from the border area to destination is deterministic with no potential for death or failure.
- All migrants assess their situation after 6-months of working.
- All migrants have the same relative financial 'goal' that determines when they return home.

- If a migrant is still in debt to an employer or intermediary (i.e., debt to industry) they cannot go home.
- All employed migrants at destination without a work permit will try to get required documents if prompted with the decision to get new documents (different then 'interaction with broker', agents must be prompted to decide to accept).
- Migrant agents with lower precarity scores are more likely to invite their family member to migrate. All migrants that invite their family member to migrate and know there is vacancy at their employment will offer the employment to their family.
- All migrants that increase their wealth during a migration also have an increased influence on others to migrate.
- All migrants that decrease their wealth during a migration also intentionally 'forget' their planning network contacts to not recommend them to others or use them for future migrations.
- Migrants that are not achieving their financial 'goal' or satisfying their employment preference are more likely to attempt to change their employer.

Rational for decision-model choices. The behaviours and decisions that have been formalised in the Sub-Model rules have corresponding rationale listed in the Sub-Model process descriptions in Section A.7.17 Tables.

A.7.5 Individual decision-making

Subjects and objects of decision-making – Decision-making is modelled on an individual level. *Migrant* agents are the most frequent subject of decisions. A *Migrant* makes multiple decisions in one migration and the range of possible objects include whether to: migrate; accept an offer; acquire documents before departure; use transport services; to pursue an employment options; invite family; acquire new documents at destination; and/or return home or keep working. An *Employer* is the subject of the decision of whether to make an employment offer to a *Migrant*. Figure 54 gives a condensed summary of the decision points across the four sub-models.

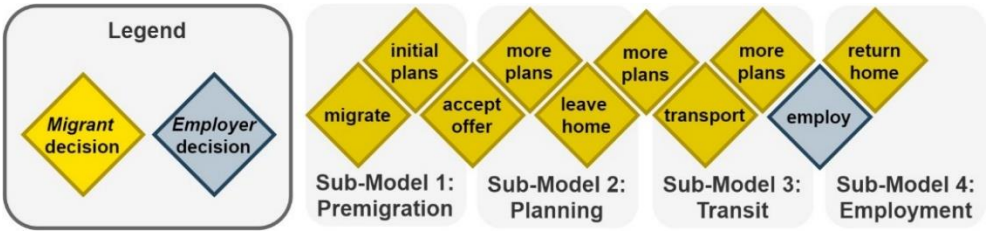


Figure 54. Decision-models across sub-models

Decision-making rationality and success criteria – A *Migrant's* overarching 'objective' that guides their sequential decision-making objectives is an explicit goal of migrating to a destination and being employed there. A *Migrant* also has an objective to meet their migration **preference** and to improve their financial situation (e.g., increase **wealth**). In the model, 'success' is a measure of whether they achieved their primary aim (migration and work), but also whether they increased their **wealth**, met their **preference**, and their level of **precarity** at destination (the latter is not an 'objective' of the Migrant agents but a 'success' criteria in the model).

Agent decisions – In Sub-Model 1, a Migrant agent decides to migrate by either accepting an **unsolicited offer** to migrate or by having 'enough' **motivation** (i.e., motivation $\geq$ motivationThreshold). A Migrant decides whether to accept an offer by comparing the **offer** properties to their migration preference, but also by having a **motivation** that is within a certain distance of their **motivation threshold**. A Migrant also makes other

decisions about their migration **plan,** and which **offers** to accept again based on their **preference**, but also based on their networks and any **plan** properties that are already populated. The conditions, parameters, and in some cases, probabilities for all Migrant decision-models are detailed in their respective Sub-Model process (Section A.7.17). When an Employer receives a request from a *Migrant*, the *Employer* decides whether to make an **employment offer** based on their employee vacancy (i.e., currentEmployees < maximumEmployees) and whether the *Migrant's* **documentation** matches the *Employer's* **required documentation**.

Agent adaptation to changes in endogenous or exogenous state variables – In some cases, a *Migrant's* migration **preference** (e.g., a destination with a large **social** network, a more 'comfortable' indoor job site, such as a factory or hospitality venue) mean that their decision to accept **offers is** responsive to some of the dynamic endogenous state variables in the model (e.g., the total population of other migrants from their home area at the destination, vacancies at manufacturing or service *Employers*). A *Migrant's* decisions are also responsive to the emergent migration networks of their **family** and returnee *Migrants* in their **home** area.

Social norms and cultural values in decision-making – Neither social norms nor cultural values have been explicitly included in the decision-models. However, Sub-Model 1 includes a variable that represents social 'influence' that may increase or decrease a Migrant's motivation to migrate. This 'catch all' influence can be interpreted as a proxy for the range of social influences on the motivation and then decision to migrate.

Spatial aspects in decision-making – A *Migrant's* **home** may influence the **offer** they will accept if they have a **preference** to stay near their **home** (i.e., preference = proximity). Additionally, the sub-area a *Migrant* is in determines which type of *Intermediary* interactions are possible as not all types of *Intermediary* extended-classes are in all sub-areas. Lastly, the **destination** of family members and other Migrants from a Migrant's home area will also determine which offers a Migrant receives through their wider networks, and accepts (i.e., preference = social).

Temporal aspects in decision-making. If a *Migrant* in planning state has not accepted an offer for 30 time-steps, they are prompted to decide their destination or discontinue their migration. Temporal aspects are not conditions for the decision, only whether and when to make the decision.

Decision-making under uncertainty. The MyTh MaP-IN ABM does not formalise 'uncertainty' as an influence on decision-making explicitly although there is some uncertainty that is implicit in Migrant's decision-making processes. For example, Migrants accept 'offers' to populate their migration plans with a set of properties, but these plans are not always a **guarantee** of migration outcomes (e.g., a Migrant may not always get a job at the employer in their plans based on an offer they received from an Intermediary or family member). At some points in the model, Migrants use the offer of an '**employer'** as a condition that influences their likelihood to **accept an offer.** This implies that an offer including an employer is more preferential in some situations in part because the assumption is that having an employer offer/plan provides a degree of more certainty of employment at destination but overall, there will still always be the uncertainty described previously – i.e., that an employer plan might not actualise as employment – but this uncertainty is the same for all migrants and not explicitly formalised in the decision rules. Decision-making under uncertainty is an area for future work (See Section A.7.22), that requires more dedicated exploration of the various models of decision-making processes under uncertainty which is beyond the scope and data available in this PhD thesis work.

A.7.6 Learning

Individual learning. *Migrant* agents learn from their migration experiences. Before they return to pre-migration state, regardless of what stage of migration they are currently in, they update their **influence** (1) and **preference** (2). A *Migrant* returning from *Employed* state also updates their **planning network** (3) based on their migration outcomes. Change in **influence** and **planning network** affect how a *Migrant* influences others' migration decision. Changes in **preference** and **planning network** affect their own possible future migrations

Collective learning. There is not explicit *collective* learning in the model. However, over time, the cumulative effect of changes from *individual* learning affects the aggregate 'influences', but also changes in planning networks and preferences may influence the overall trends in migrant destination choices which for some migrants with a 'social' preference (i.e., the preference to go where others are) might indirectly present as collective learning if migrants are following emergent pathway trends based on individual learning.

A.7.7 Individual sensing

Individual sensing of endogenous and exogenous elements. Agents can sense some properties of other agents (endogenous elements) and spatial features of the model (exogenous elements) (Table 43).

Table 43. Endogenous and exogenous model elements

	Endogenous	**Exogenous**
Migrant	• all agents in their **vision** • **destination** of other **home** *Migrants* • **employment state** of **family** • **wealth** of other **home nuclear families** • *Migrants'* **migration** history	• **boundaries** of sub-areas • **locations** of *passport offices*, *agencies*, *border crossings* • **location** of their **employer plan**
Intermediary	• *Migrants* in their **vision**	• **boundaries** of sub-areas • *Myanmar-Doc-Brokers* sense **location** of *passport offices*
Employer	• N/A	• N/A

Individual sensing of other individuals' state variables – Agent 'sensing' of other agents' state variables depends on some spatial or social condition being met before the exchange of information is possible. When the condition is met the exchange is automatic. For example, two *Pre-migration-Migrants* located in each other's **vision** will automatically exchange **influence**. Agent sensing is never erroneous, that is, *Migrants* always sense accurate information about other *Migrants* and about spatial elements. For example, a *Migrant* agent senses their own **nuclear family's wealth** *and* all other **nuclear families' wealth** of their **home** area without modelling an explicit transfer of this information and the 'value' of the **wealth** properties they sense are always accurate.

Spatial scale of sensing – The spatial scale differs depending on the interaction taking place. For example, family members can interact across the full model space (i.e., it does not matter how far two family members are away from each other, they can still interact). Other *Migrant-Migrant* interactions or *Migrant-Intermediary*, *Migrant-Employer* interactions depend on spatial proximity which is defined in this model as '**vision'** which is a set diameter space around the agent node in the model. This visual field can be increased for some rules.

Mechanisms of obtaining information – Some exchange of information requires direct links or proximity (e.g., **influence**, **offer**) and these types of exchanges are explicitly modelled in the Sub-Model processes. Other information exchange is implicit, such as knowledge of home area wealth distribution or location of spatial features.

Costs of cognition or gathering information – There are two points in the model where there are explicitly executed but are indirect 'cost for cognition'. First, when a *Transit-Migrant* is trying to find a *Smuggler* **offer** in Myawaddy it increases their time in transit which incrementally increase their cost of migration since there is a 'daily' cost for being in transit. Second, when a *Transit* or *Employed-Migrant* is trying to find an Employer **offer** in destination there is an opportunity cost for the time-steps is takes them to find an *Employer* because this delays possible earnings.

A.7.8 Individual prediction

Type of data agents use to predict future conditions. A *Migrant* agent use the information they are given in the **offer** to predict their migration process and future employment. *Migrant* agents also use their sensing of their family and home community Migrant's location to predict their fellow Migrants at specific **destinations**. *Intermediary* and family *Employed-Migrant* agents use *Employer's* **vacancy** to predict if there will be employment for a *Migrant* once they arrive.

Type of behavioural models that agents use to estimate future conditions. In some cases, Migrants use a basic utility maximisation model to compare offers and choose one that has employment, highest ages, and, in some cases, closer spatial proximity to their home area.

Potential for erroneous predictions. Migrants' decisions and the implicit predictions they are making in these decisions (i.e., to have employment when they arrive, to arrive at a destination where family is, etc.) are based on the information they sense in the model or information that is communicated to them through interactions. Their sensing is not erroneous (i.e., they are sensing the 'correct' information about their environment, and they receive the 'correct' information the other Agent is communicating), but it is possible that a Migrant's outcome does not reflect the prediction they were making in their decision. For example, a Migrant might be given an employer offer by a family member but by the time they arrive there is no vacancy at that job site. The information was not erroneous ('wrong'), but the prediction was incorrect as because of the dynamic nature of an Employer's vacancy.

A.7.9 Interaction

Direct and indirect agent interactions. Agent interactions are almost entirely direct. The exception is that some agents transfer indirect offers to a *Migrant* via their network **links**. Table 44 summarises the interactions, whether they are direct[D] or indirect[In], and changes to **properties.**

Table 44. Agent-Agent interactions by sub-models

	Agent-Agent interactions and **properties** affected
1: Pre-migration	• A *Migrant* can influence[D] a *Pre-migration-Migrant's* **motivation** to migrate. • A *Pre-migration-Migrant* can receive[D] and accept[D]/reject[D] unsolicited **offers** from a(n): **1)** *Facilitator;* ***2)*** *Employed-Migrant* (**family**); OR **3)** *Recruiter*. ▪ An unsolicited **offer** can also link[In] to another *Intermediary,* which presents the *Migrant* with the option of accepting[D] a **combined offer.**
2: Planning	**Sub-Model 2-A:** • A *Planning-Migrant* without an accepted **offer** can request[D] an **offer** from an agent in their **planning network**. ▪ If a **planning network** agent receives[D] a request they can respond[D] with a solicited **offer**. • A solicited **offer** can also link[In] to another *Intermediary,* which presents the *Migrant* with the option of accepting[D] a **combined offer.** **Sub-Model 2-B:** • A *Planning-Migrant* near a passport office can receive[D] and accept[D]/reject[D] an unsolicited **offer** from a *Myanmar-Doc-Broker.* ▪ An unsolicited **offer** from a *Myanmar-Doc-Broker* can also link[In] to a *Recruiter,* which presents the *Migrant* with the option of accepting[D] a **combined offer.**
3: Transit	• A *Transit-Migrant* that needs transport can request[D] an **offer** from a *Smuggler* in their **planning network** or within their **vision**. ▪ If a *Smuggler* receives[D] a request they can respond[D] with a solicited **offer**. • An *Employer* can receive[D] and accept[D]/reject[D] a request for an **employment offer**. ▪ A *Transit-Migrant* then accepts[D] that **employment offer**. • A *Transit-Migrant* pays[D] the **fees** to all *Intermediaries* once they arrive in **destination**.
4: Employment	• An *Employed-Migrant* can make an unsolicited **offer** to a *Pre-migration-Migrant* in their **family** (*Pre-migration-Migrant's* response[D] detailed in Sub-Model 1). • A *Thai-Doc-Broker* can receive[D] and accept[D]/reject[D] a request for a **documentation offer**. ▪ An *Employed-Migrant* can then accept[D] that **offer** from the *Thai-Doc-Broker*. • An *Employer* pays[D] an *Employed-Migrant* their **wages.** • An *Employed-Migrant* can pay[D] off their **debt** to their *Employer*.

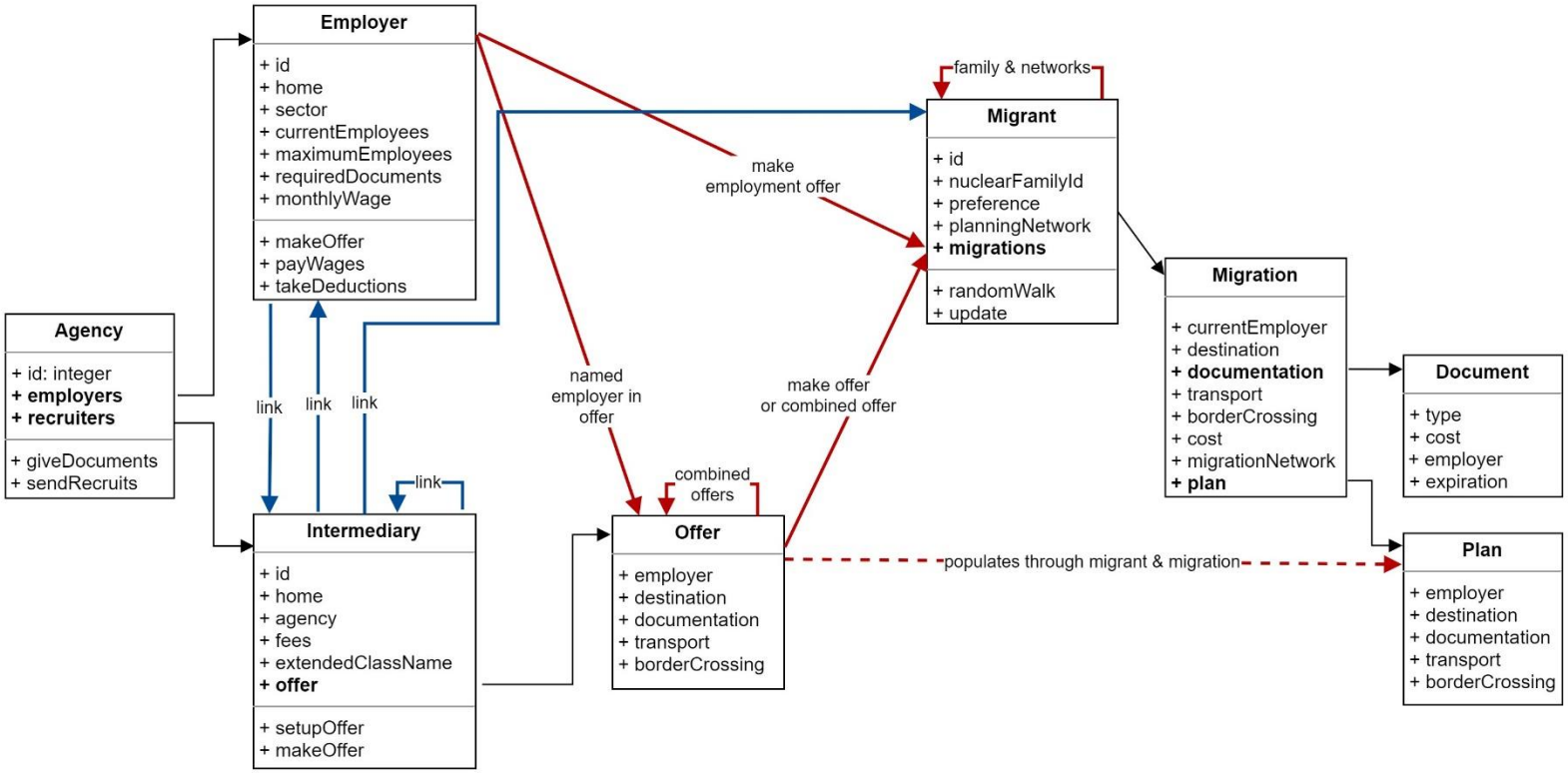
Conditions for interactions. Interactions depend on either spatial proximity (i.e., within **vision**), social proximity (i.e., **nuclear/extended family** or **home**), or network links. Interactions are conditional on other factors, such as agent properties or, in the case of a *Migrant*, plan and migration properties. The conditions are detailed in Section A.7.17.

Communication in interactions. Offer transactions (e.g., requesting, making, receiving, accepting, rejecting, or combining offers) are the primary form of communication. Table 45 describes the information communicated in every possible offer, including combined offers through network links. Figure 31, repeated below, is a simplified version of the UML diagram depicting how agent interactions and offers populate a Migrant's **migration** and **plan.**

Coordination networks. Relational links influence the offers a Migrant receives and offers they request. Some of the network links are imposed and others emerge during the model run.

Table 45. Offers and combined offers

DECISION-MAKER	PLAN property	all possible VALUES	populating plan without a *pre-migration* offer	populating plan with accepted offer					
				+ R	*+ MDB*	*+ S*	+ F	+EM	*+ TDB*
Migrant	employer	employer id	decide during planning, transit, or employment	✓	✖	✖	✓	✓	✖
	destination	'bangkok', 'phang nga', 'tak', 'mae sot'	decide during planning	✓	✖	✓	✓	✓	✖
	documentation	['border pass', 'work permit', 'passport', 'none']	decide during planning or employment	✓	✓	✓	✖	✖	✓
	transport	smuggler, recruiter, or migrant id	decide during planning or transit	✓	✖	✓	✖	✖	✖
	border crossing	'official', 'unofficial1, 'unofficial2'	decide during planning or transit	✓	✖	✓	✖	✖	✖
OFFERER	**OFFER property**	**offer possible VALUES**	**populating offer property**	**Base Offer Modifiers**					
Recruiter (R)	employer*	employer id	any from recruiter's agency's employer **roster**	✖	✖	✖	✖	✖	✖
	destination*	'bangkok' or 'phang nga'	always: employer's **home**						
	documentation	['work permit' and 'passport']	always: both **types** in combination						
	transport	recruiter id	always: recruiter's own **id**						
	border crossing	'official'	always: 'official'						
Myanmar-Doc-Broker (MDB)	employer	✖	-	✖	✖	✖	✖	✖	✖
	destination	✖	-						
	documentation	'passport'	always: 'passport'						
	transport	✖	-						
	border crossing	✖	-						
Smuggler (S)	employer	✖	-	✖	✖	✖	✖	✖	✖
	destination	'bangkok' or 'phang nga' or 'tak'	random: 'bangkok' (50%), 'phang nga' (30%), 'tak' (20%)						
	documentation	'none'	always: 'none'						
	transport	smuggler's id	always: smuggler's own **id**						
	border crossing	'unofficial2'	always: 'unofficial2'						
Facilitator (F)	employer	employer id	sometimes: from facilitator's **links** / otherwise: empty	R	F ✖	F ✖	✖	✖	✖
	destination	'bangkok' or 'phang nga' or 'tak' or 'mae sot'	employer's **home** / random: 25% chance each destination	R	F	S			
	documentation	✖	-	R	MDB	S			
	transport	✖	-	R	✖	S			
	border crossing	✖	-	R	✖	S			
Employed-Migrant (EM)	employer*	employer id	sometimes: own **employer** IF vacancy / otherwise: empty	R	EM ✖	EM ✖	✖	✖	✖
	destination*	'bangkok' or 'phang nga' or 'tak' or 'mae sot'	always: current **destination**	R	EM	S			
	documentation	✖	-	R	MDB	S			
	transport	✖	-	R	✖	S			
	border crossing	✖	-	R	✖	S			
Thai-Doc-Broker (TDB)	employer	✖	-	✖	✖	✖	✖	✖	✖
	destination	✖	-						
	documentation	'work permit' and/or 'passport'	always: offer both **types** in combination or separate						
	transport	✖	-						
	border crossing	✖	-						



Repeated Figure 31. Simplified UML diagram specific to agent links and offers

A.7.10 Collectives

Agent aggregations. Agents are aggregated in family groups and networks via links. Some of the network links are imposed and others emerge during the model run (Table 46).

Table 46. Agent networks – imposed and emergent

Imposed network	Emergent network

• Nuclear and extended families
• *Intermediary* unidirectional links:
  ▪ *Facilitator – Recruiter*
  ▪ *Facilitator – Smuggler*
  ▪ *Myanmar-Doc-Broker – Recruiter*
• *Agency-Agent* links
  ▪ *Agency-Recruiter*
  ▪ *Agency-Employer*
• *Intermediary-Employer* unidirectional links:
  ▪ *Recruiter – Employer*
  ▪ *Facilitator – Employer*
  ▪ *Smuggler – Employer*
• *Employer-Intermediary* unidirectional links:
  ▪ *Employer – Thailand-Doc-Broker*
	Each *Migrant's* **planning network:**
	• *Migrant* bidirectional links
	• *Intermediary* bidirectional links, any *Intermediary* extended-class
	
	Each **migration network**:
	• *Migrant* bidirectional links
	• *Intermediary* bidirectional links, any *Intermediary* extended-class
	• *Employer* bidirectional links

Network and links' effect on Migrants:

- Nuclear and extended families affect wealth, influence, motivation, and offers received.
- *Intermediary-Intermediary* links form combined offers.
- *Agency-Employer* and *Agency-Recruiter* links determine employer offers from Recruiters.
- *Intermediary-Employer* links determine employer offers.
- *Employer- Thailand-Doc-Broker* links give access to new documentation at destination.
- A **planning network** informs which agents receive a Migrant's request.
- A **migration network** helps form a Migrant's plan and migration, but also is a group of links that a Migrant can share with other Migrants.

Collective representations. *Intermediary-Intermediary, Intermediary-Employer,* and *Employer-Intermediary* links are represented as straight lines between the agents in the model. Family aggregations are also represented as lines between *Migrant* agent nodes in the same family.

A.7.11 Heterogeneity

Heterogenous properties or behaviours. Most of the agent properties, apart from **vision** and **stepSize**, for all three agent classes are heterogenous and the ranges of possible values for each property is described in Table 41 (in section A.7.2 above).

Heterogeneous decision-making. *Migrants'* decision rules, some of the conditions for these rules, and the order of execution of these decisions are the same. However, *Migrants'* **networks** (that partly determine the **offers** they receive) and *Migrants'* migration **preferences** (a decision-making parameter) are heterogenous inputs to the decision process. Some *Migrants* have more decision points (e.g., decide destination, decide border crossing) if they have not accepted **offers** that include these **plan** properties. *Employers'* decision models for the employment offers are not heterogenous.

A.7.12 Stochasticity

Random or partly random processes in the model. Agents' initialised location, links, and many property values are assigned randomly, sometimes randomly within class, extended class, or sector. See Table 41 (in section A.7.2 above) for which properties are initialised randomly and how. *Migrant* and *Intermediary* agents execute random walks at different points in the sub-model processes. *Intermediary* and *Employer* links are also initialised randomly based on predetermined probabilities detailed in section 7.15. *Migrant* and *Employer* decision-making is probabilistic once the prior conditions for activating the decision process have been satisfied.

A.7.13 Observation

Data collected from the ABM – Data is logged every time-step, and each 'run' dataset is outputted as a JavaScript Object Notation[27] (JSON) file at the end of every model run (i.e., after 1,825 time-steps). The model analysis explored four key outputs:

1. Total *Migrants* in each **state** (see A.17.13a);
2. Total **accepted offers** by *agent type*(s) (see A.17.13b);
3. *Migrants'* **precarity score** averaged by **pathway** (see A.17.13c); and
4. Composition of the **sociocentric migration network** (see A.17.13d).

Emergent results. The primary emergent properties of the model runs are the individual migration precarity scores (by pathway type) and the composition of the model's sociocentric network.

A.17.13a Output 1 – Migrants' states

The total migrants will be charted by which state (pre-migration, planning, transit, employed) they are in at each time-step starting from time-step 1 (t_1) until the end of the model run (t_{1825}). See Figure 55 for an example of the output graph.

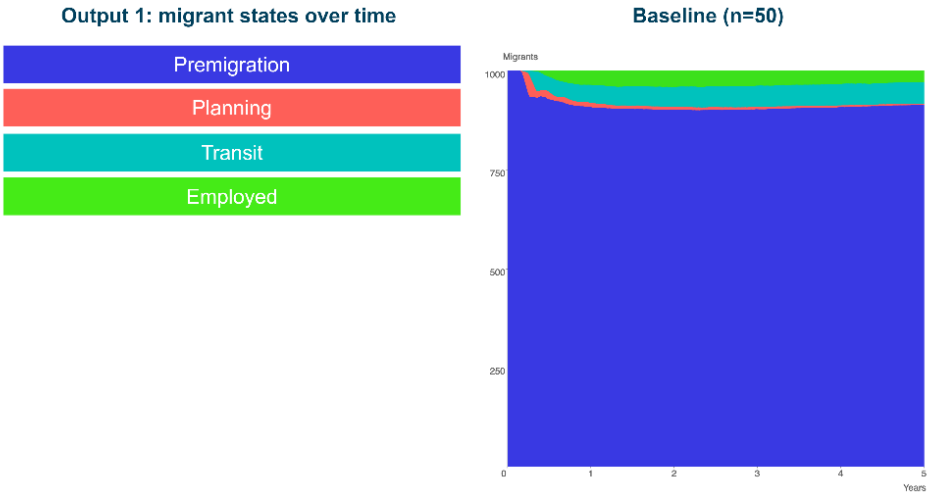


Figure 55. Output 1 – example graph

[27] A 'JSON' file stores simple data structures and objects in JavaScript Object Notation (**JSON**) format, which is a standard data interchange format. It is like a Comma-Separated Values (CSV) file.

A.17.13b Output 2 – Accepted offers

The cumulative total offers that have been charted by the type of agent making the offer (i.e., family, Myanmar Document-Broker, Recruiter, Smuggler, Facilitator, or Thailand Document-Broker). See Figure 56 for an example of the output graph.

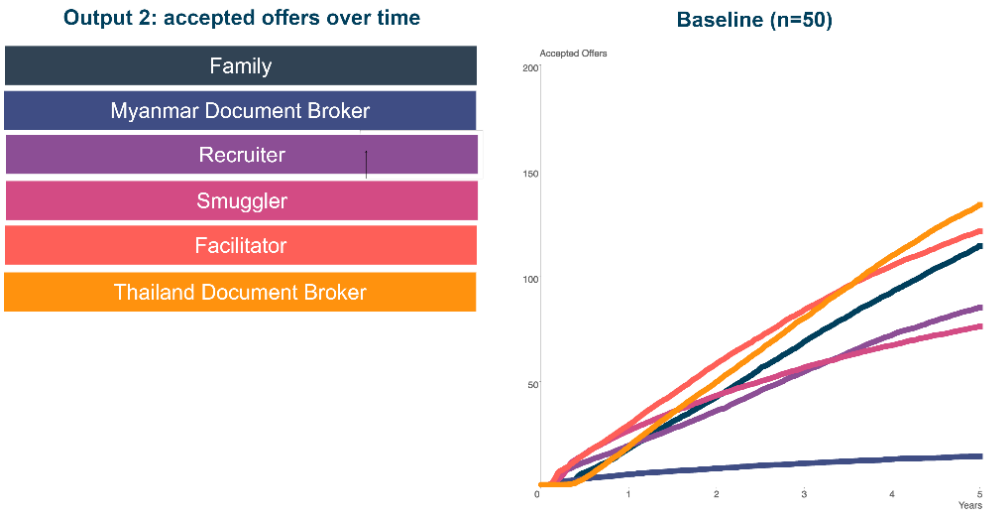


Figure 56. Output 2 – example graph

A.17.13c Output 3 – Precarity scores by pathway

The formalization of the 'precarity' score is informed by Hannah Lewis's work exploring conceptualizations of migrants experiences of *hyper*-precarity (26), Priya Deshingkar's work exploring brokered precarity in the Global South (59) and Myanmar specifically (62, 63), and by the empirical Myanmar-Thailand MMSNA conducted as part of this study (215). The **precarity** score is calculated for each migration starting in the time-step that migration costs are paid (Sub-Model 3, Rule 21). **Precarity** is a multi-dimensional score that includes indicators for the individual's current livelihood pressure, socio legal status (i.e., legal status affects social conditions), and destination knowledge and support that all contribute varying 'values' to the migrant's overall precarity score (Table 47).

Table 47. Individual precarity score indicator

Precarity Score Elements	Precarity Score Indicators	IF TRUE add to score*
Livelihood Pressure	1. debtFamily(t) > wealth(t)	0.1
	2. debtIndustry(t) > 0	0.2
	3. familyWealth is in lowest 25% of households	0.1
	4. monthlyWages < .09 (i.e., below minimum wage)	0.1
Legal status	5a. no documents and in Mae Sot or Tak	0.1
	5b. no work permit and in Bangkok or Phang Nga	0.2
Knowledge & support at destination	6. this is the migrant's first migration	0.1
	7. no family at destination	0.1
	8. no viable, attractive alternative jobs (i.e., vacancy and higher wages and required documents satisfied)	0.1
*IF FALSE then value for that indicator is 0		
precarityScore(t) = sum of precarity score indicator values that that apply (Score can range from 0-1)		

The overall precarity score is calculated as an average of the sum of all individual migrations' precarity scores that used the same **pathway.** There are 4 possible pathways that represent all possible migration trajectories in the model and are mutually exclusive and defined by the types of offers the *Migrant* has accepted (Table 48).

Table 48. Pathway classifications

Pathway Classifications	Pathway Classification Descriptions
Solo	Migration network only includes the migrant
Family	Migration network only includes family member(s)
Informal	Migration network includes at least one intermediary but does not include a recruiter intermediary
Regular	Migration network includes a recruiter intermediary

This score is dynamic as it responds to changes that occur through wage payments, family financial changes, documentation changes, influx of migrants, changes to debt, etc (Figure 57). The indicators included in the precarity score are chosen for the following reasons:

- **Debt (indicators 1&2)** indicates pressure to recover migration **costs**. Industry debt prevents migrants from *leaving* and family debt exceeding current wealth demotivates migrants from returning home.
- **Nuclear family wealth (3)** is a proxy for pressure to remit money home and current relative financial standing that may have motivated the migration in the first place.
- **Low wages (4)** increase financial pressure on the migrant, especially when in a destination with higher costs of living than their home area.
- **Documentation (5),** or lack thereof, increases the risks of deportation and exploitation and limits migrants' rights and security at destination. There appears to be an increasing vulnerability with distance from the border areas where irregular migration is more common and there is more opportunity to cross the border quickly if needed.
- **First migrations (6)** are usually characterised by more uncertainty due to a lack of familiarity with the context and how to navigate the context safely.
- **No family at destination (7)** means the migrant has less support to rely on if issues arise.
- **Knowledge of alternative jobs (8)** gives migrants an option to leave their current work, if exploitative or dangerous, without losing livelihood. No knowledge of viable and attractive alternative work increases the pressure migrants feel to stay at their current job despite the conditions.

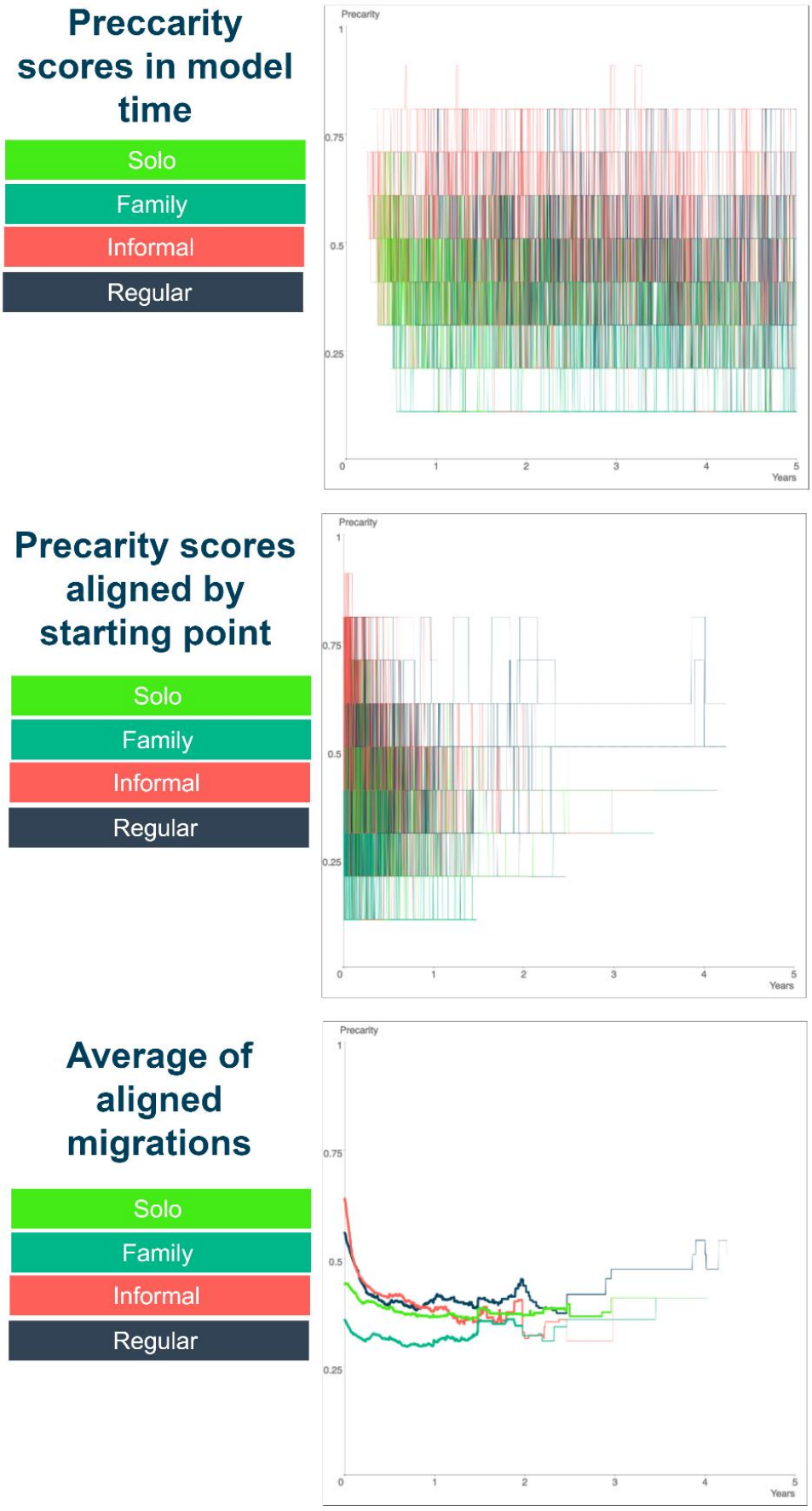


Figure 57. Output 3 – example graph

A.17.13d Sociocentric migration network density

The model run will produce an emergent sociocentric network that includes all *Migrants* that initiated at least one migration and all *agents* (family, intermediaries, employers) in those migrations' **migration networks**. The sociocentric network structure indicators (size, density, and diversity – see Table 49) will be captured for each year (n = 5) for one model run as a narrative case example of the emergence of the model's network. See Figure 58 for an example of the network visual.

Table 49. Network indicators

Network Indicators	Network Indicator Description
Size	Proportion of total agents in the network each time-step.
Density	Proportion of 'potential links' that are present in each time-step.
Diversity	Proportion of different agent classes and extended classes in the network at the end of the model run

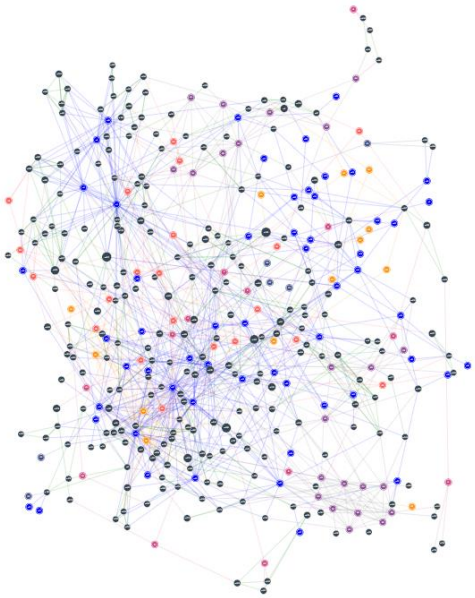


Figure 58. Output 4 – example emergent sociocentric network visualisation

Simulation scenarios. The analysis of the MyTh MaP-IN model considers three scenarios (one baseline and two experiments) and compares the dynamic observations across these scenarios.

The two experiments represent two key principles in the 'fair recruitment' intervention model that are specific to the migration planning and execution process. First, that recruitment should always be carried out within the law, and thus within official migration channels. In the case of the Myanmar-Thailand corridor this is the MOU process or post-arrival verification. Second, migrant workers should not bare the costs of recruitment services (i.e., Employer Pays Principle). These three scenarios are formalised in the ABM as follows:

4. **Baseline:** no pre-set scenario characteristics added to the model design.
5. **Legal Migration:** close both 'unofficial' border crossings so any *Migrant* attempting to cross the unofficial way immediately gets sent home.
6. **Employer Pays:** all *Recruiter* fees are set to 0.

Each scenario was run 50 times. The results for each output are shown as the mean values and ranges across all runs.

A.7.14 Implementation details

Mode implementation – The MyTh MaP-IN conceptual model and sub-model processes (as detailed in Section A.7.17) have been translated into model code written in JavaScript. The final ABM visualisations have also been written in JavaScript using the P5js and D3js visualisation libraries. This method of implementation was chosen in part to allow wider stakeholder access to the model in a browser-friendly viewing format (avoiding barriers of needing to download or navigate unfamiliar software such as NetLogo), as well as to enable more visual customisations to foster better model comprehension for non-technical audiences.

Model access – The MyTh MaP-IN model code, ODD+2D protocol, and supplementary documentation can be accessed via GitHub (305). The model can be viewed and interacted with via browser:

www.alysmcalpine.com/research/mythmapin/

The model is in the process of being made public via the CoMSES OpenABM model library (262).

A.7.15 Initialization

Initial state – At initialisation of the model (i.e., time-step = 0, or 't0') the environment is setup, and the *Migrant*, *Intermediary,* and *Employer* agents are created, as described in Section A.7.2. Some agent properties are pre-loaded at initialisation (e.g., motivation, threshold, vision) and other properties are left empty to be populated during the model run (e.g., migrations, plan, migration network). Table 50 details the population distribution of each agent's class by one other agent property (i.e., *Migrant-**state**, Intermediary-**extended class**, Employer-**sector**).* Table 41 details how the agent properties are initialised.

Table 50. Initialised agent populations in each sub-area

	Agent Groups	Origin sub-areas					Destination sub-areas				Total
Agent Class	*Migrant* **states** *Intermediary* **class** *Employer* **sectors**	Bago	Rakhine	Magway	Yangon	Myawaddy	Mae Sot	Tak	Phang Nga	Bangkok	
Migrant	**Pre-migration-** *Migrant*	100	100	200	400	200	-	-	-	-	1,000
	Planning- *Migrant*	-	-	-	-	-	-	-	-	-	0
	Transit- *Migrant*	-	-	-	-	-	-	-	-	-	0
	Employed- *Migrant*	-	-	-	-	-	-	-	-	-	0
Intermediary	**Recruiter**	-	-	-	20	8	-	-	-	-	28
	Facilitator	5	5	8	2	2	-	-	-	-	22
	Smuggler[1]	-	-	-	-	15	-	-	-	-	15
	Thailand-Document-Broker	-	-	-	-	-	3	-	5	10	18
	Myanmar-Document-Broker	-	-	3	5	3	-	-	-	-	11
Employer	**Manufacturing**	-	-	-	-	-	8	3	3	12	26
	Services	-	-	-	-	-	8	-	8	8	24
	Construction	-	-	-	-	-	5	-	3	5	13
	Fishing	-	-	-	-	-	-	-	3	6	9
	Agriculture	-	-	-	-	-	-	3	3	-	6
	TOTAL	105	105	211	427	228	24	6	25	41	1,172

1. Smugglers are initialised in a smaller Myawaddy sub-area within a constrained random walk to that area.

Run initial state variation – Model *runs* (i.e., repeated sets of 1,825 executed *time-steps*) will always be setup with the same default *environment,* number of *agents* in each sub-area, *value ranges* of agent properties (e.g., number of families in the model, threshold range), and *distributions of values* (e.g., proportion of migrants with the three different migration preferences). However, each individual *agent's* initialised *property values* will vary across the runs. The number of agents in the groups described in Table 50 are the default population distributions for each run across the sub-areas. The model will include some user-controlled parameters which the ABM user can interact with and adjust at the start of a model run to change some of the model's initialised values (See Section A.7.17).

Rationale for initialised collective and network values – The initial values of the agent types, locations, and links between *Intermediaries* were informed by the empirical egocentric network data and qualitative data (See Section A.7.16). The initialised unidirectional links (Agent A to Agent B) that are included in the model and what percentage of the time these links exist are detailed in Table 51.

- *Recruiters* can only be **linked** to *Employers* in their *Agency's* **roster**.
- *Smugglers* can only be l**inked** to *Employers* in their **offer's destination**.
- *Employers* can only be **linked** to *Thai-Doc-Brokers* in their **home** area.

Table 51. Initialised agent-agent links

'A' has link to 'B' x% of the time		AGENT B					
		Facilitator	Recruiter	Myanmar-Doc-Broker	Thai-Doc-Broker	Smuggler	Employer
AGENT A	Facilitator		✓ 25%			✓ 100%	✓ 25%
	Recruiter						✓ 100%
	Myanmar-Doc-Broker		✓ 10%				
	Thai-Doc-Broker						
	Smuggler						✓ 10%
	Employer				✓ 50%		

A.7.16 Input data

Data overview – The model does not use any direct input from empirical data files or data imported from other model data outputs. However, the structure and rules are informed by empirical data sources analysed using mixed-methods social network analysis (as described in Section A.7.4 and McAlpine and colleagues MMSNA paper (215)). The primary data analysed for this ABM included two datasets:

1. Structured egocentric network data and outcome variables formatted into three Comma Separated Values (CSV) files:
    - Migrant file – demographic and outcome data pertaining directly to the interviewee
    - alter file – demographic and behaviour data pertaining to all the alters the interviewee named and described in the participatory egocentric network mapping
    - Link file – the relational links between alters in the interviewee's egocentric network
2. Qualitative transcripts –text files coded according to a priori themes and themes that emerged through a deductive qualitative analysis approach.

Separate from these empirical datasets that informed the model rules, the model has an input data file called a 'config' file. Configuration data 'inputted' into the model is stored in a JSON file that populates the model with essential parameters as defined and described in the Sub-Model descriptions. Alternative configuration files can be exported via the model interface after using the parameter sliders to select the desired values. Separating initialisation data from the model code in this way allows for using different initialisation values for different model runs during analysis.

Data structure – The mixed methods empirical data were used to inform the agent entities, environment entities, and agent rules (1 & 2 below with some examples). The config file was used to generate the entities and properties in the model code in a structured manner. More detailed **data mapping** and

data patterns (i.e., the ODD+2D sections on the linkages between data sources and model design) are integrated into the Tables in Section A.7.17 that describes each model rule. The rationale for each rule, whether supported by empirical data or theory, is included there and informed by the findings detailed in McAlpine and colleagues' MMSNA paper (215). See Table 52 for an overview of the data input and config files.

Table 52. Data inputs and config file

Data type	Description
1. Structured data	• Origin and destinations determined the environment sub-areas. • Network nodes informed the Intermediary types. • Network events/interactions informed the agent rules. • Outcome variables (e.g., wages, deductions, work hours) informed the *Employer* variables.
2. Qualitative data	• Accounts of network interactions informed the agent rules, model stages, and order of execution. • Descriptions of decision-making processes and preference informed the decision-models.
3. Config File	• *Environment* names, locations, boundaries, subareas • *Agency* and *Document Office* names and locations • Quantity of *Migrant* agents in each *Environment* subarea • Quantity of *Intermediary* agents by class in each *Environment* sub-area • Quantity of *Employer* agents by sector in each *Environment* sub-area • Require documents and maximum employees for each sector • Probability distributions for *Intermediary-Intermediary* links • Probability distributions for *Intermediary-Employer* links • Probability distributions for *Employer-Intermediary* links • Properties for *Documents* including expiration, cost, and *Employer* id • Maximum and minimum money values for model's financial scale

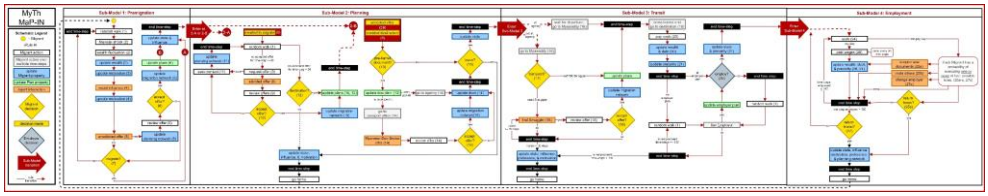
A.7.17 Sub-models

MyTh MaP-IN includes four sub-models:

1. Pre-migration
2. Planning
3. Transit
4. Employment

Sub-model design. The sub-models, presented sequentially in this section of the ODD+2D protocol, are written from the perspective of an individual *Migrant* agent. Each sub-model description includes a:

1) **narrative overview;**
2) **schematic diagram** (Figures 59-62, sub-model subsections of Figure 32 repeated below); and
3) **table of rules** (Tables 53-56, brief description, rationale, and model-based execution for every rule)



Repeated Figure 32. MyTh MaP-IN model schematic[28]

[28] Please note, if you are viewing this figure digitally you can zoom-in for detail, otherwise please refer to Figures 59-62 later in this section for larger versions of the individual Sub-Model schematics.

Model parameters – Please refer to the documentation on the entity properties (Table 41), agent-agent links (Table 51), and agent-agent interactions (Tables 44 and 45) to note the possible values or configurations of these model properties that are included in the sub-model rules.

User controlled parameters

The interactive interface includes the option to run the two experiment scenarios, as well as the baseline scenario, without needing to make changes to the model code. Future iterations of the model will include more user-controlled functions for more model exploration (e.g., changes to migrant preference distributions, changes to agent population totals and densities).

Sub-Model 1 – Pre-migration

Narrative Overview

The primary agent that executes the process in Sub-Model 1 (See Figure 59 and Table 53) is a *Pre-migration-Migrant*. A *Pre-migration-Migrant* decides if they want to migrate by either:

a) accepting an unsolicited **offer** to migrate from an *Employed-Migrant* in their **family** that is already at **destination**;
b) accepting an unsolicited **offer** to migrate from a *Facilitator* OR *Recruiter* within their **vision**; or
c) having a **motivation** to migrate that reaches or exceeds their **motivation threshold**.

Every time-step, a *Pre-migration-Migrant's* **motivation** changes based on their **nuclear family's relative average wealth** and the social **influences** they receive from family and from *Migrant* agents in their **vision**. In Sub-Model 1, an accepted **offer** populates a *Migrant's* **plan** with a **destination** and sometimes an **employer**. When a *Pre-migration-Migrant* decides to migrate, they update their **state** from 'pre-migration' to 'planning' and end the time-step. A *Planning-Migrant* starts the next time-step in Sub-Model 2. If they do not decide to migrate, a *Pre-migration-Migrant* repeats the **Sub-Model 1** process in the next time-step.

Figure 59 depicts the Sub-Model 1 process annotated with the rule numbers that correspond to Table 53. Table 53 presents the Sub-Model 1 *Migrant* agent rules in the order they are executed. The implicit condition for all Sub-Model 1 rules is that a *Migrant*'s **state** is 'pre-migration', and their **location** is within their **home** sub-area. Some Sub-Model 1 rules describe a *Pre-migration-Migrant's* response to rules that are 'fired' by other agents and Table 53 includes signposting to those corresponding rules in other Tables when relevant.

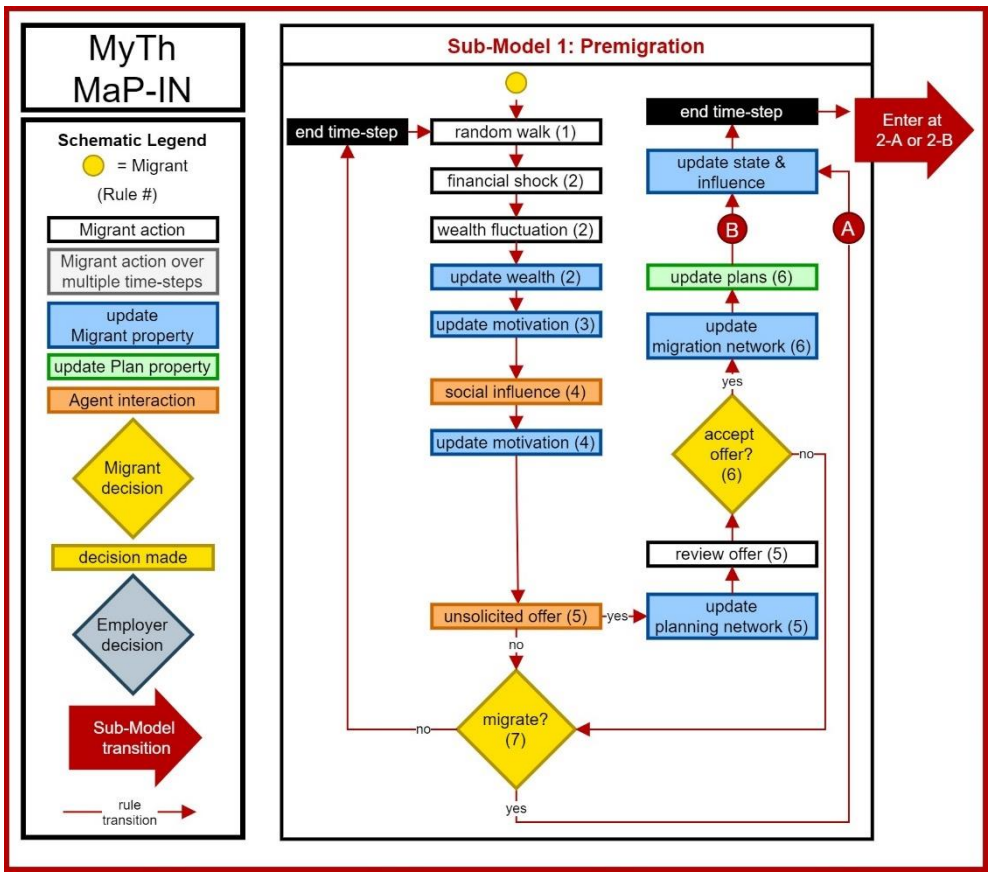
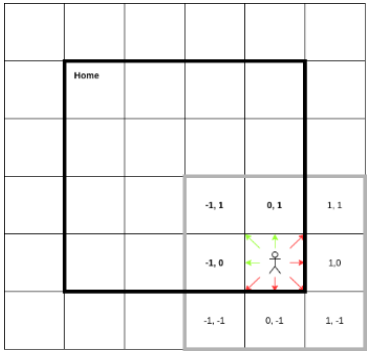


Figure 59. MyTh MaP-IN Sub-Model 1 schematic

Table 53. Sub-Model 1 rules

Rule description, rationale and calibration informed by McAlpine et. al.'s Myanmar-Thailand MMSNA study (215), University of Sussex's CHIME study (81), and the Myanmar Living Conditions survey (260).	**Model based rule** (IF-THEN or basic equation)
1. Migrant movement rules **1a. Migrant random walk rule.** A *Migrant* completes one random-walk movement to a cell in their surrounding Moore neighbourhood (3x3 grid that centers around their current location). **1b. Migrant random walk constraint.** A *Migrant* cannot random walk outside of their current sub-area (i.e., **home** in this case).  **Rationale:** Random walk incorporates stochastic movement that creates 'chance' opportunities for interaction among the agents. This pattern reproduces local interactions that reflect both serendipitous and routine points of contact that can occur when an agent is not executing 'destination' driven movement. These random movements are always within the bordered sub-area space as individuals are unlikely to go far from their geographic 'home' area unless they are migrating domestically (not included in this ABM) or internationally (occurs in future Sub-Models). These opportunities for contact capture the many local social interactions described in the MMSNA study qualitative narratives about influential social encounters leading up to the decision to migrate (direct exchanges with or indirect observations of co-workers, friends, community members, neighbours, even strangers including conversations about migration or observations of migration behaviours) (215).	**1a. Migrant random walk rule** *possibleAbsoluteStep = { [-1,1], [0,1], [1,1], [1,0] , [1,-1] , [0,-1] , [-1,-1] , [-1,0] }* *proposedAbsoluteStep = randomly selected possibleAbsoluteStep* **1b. Migrant random walk constraint** IF *location(t-1) + proposedAbsoluteStep is within agent's sub-area* THEN *location(t) = location(t-1) + proposedAbsoluteStep* ELSE *Continue to randomly select proposedAbsoluteStep until:* *(location(t-1) + proposedAbsoluteStep) is within the agent's sub-area* *location(t) = location(t-1) + proposedAbsoluteStep* END

2. Wealth change rules Migrant **wealth** can change due to infrequent **financial shocks** and/or regular **wealth fluctuations**. **2a. Financial shock rule.** There is a small random chance (0.01%) every time-step that **wealth** decreases by 30% (i.e., wealthChange = 0.7). **2b. Wealth fluctuation rule.** Once every 30 time-steps, **wealth** fluctuates by a small random amount. The **wealth fluctuation** time-step varies across *Migrants*. At model initialisation, a **monthly wealth fluctuation offset** is randomly selected between 1-30 which is used to determine when the wealth fluctuation rule is executed for an individual *Migrant* during Sub-Model 1. N.B. The % symbol in this rule is not being used to represent a percentage, but instead it is a common programming notation for the modulo operator (i.e., returns the remainder left over when one operand is divided by a second operand). **2c. Wealth change rule.** The total **wealth change** (**financial shock** + **fluctuation**) is applied to the *Migrant's* current **wealth**. **2d. Wealth constraint.** Wealth is constrained so it cannot be less than 0 or more than 1. **Rationale:** Wealth is a dynamic variable. **Regular small fluctuations** represent more predictable changes to monthly profit from pre-migration livelihood activities, such as 'normal' harvest. Since this fluctuation happens 'monthly' in the model, the initialised value of migrant 'wealth' is an approximate monthly income based on average daily spending in Myanmar rural and urban areas (260). In keeping to the model purpose and aim to keep the model as simple as appropriate, the model assumes *Pre-migration-Migrants* do not have savings, debt, or multiple incomes and the model also does not explicitly execute pre-migration employment activities. **Financial 'shocks'**, larger unexpected and sudden decreases to wealth, were reported as drivers of migration in the MMSNA and the CHIME study. Shocks included, for example, unexpected medical expenses, loss of land/property, loss of employment, climate events, etc. These shocks decrease wealth a more significant amount which is more likely to trigger the decision to migrate than a small negative fluctuation.	**2a. Financial shock rule** *wealthChange = 1 with probability = 0.9999* *wealthChange = 0.7 with probability = 0.0001* **2b. Wealth fluctuation rule** *monthlyWealthFluctuationOffset = random number between 1-30 set at initialisation and static throughout run* IF (*current timestep – monthlyWealthFluctuationOffset)%30 = 0* THEN *add randomly selected amount between -0.05 to 0.05 to wealthChange* END **2c. Wealth change rule** *wealth(t) = wealth(t-1) * wealthChange* **2d. Wealth constraint:** *wealth(t)* = MIN[1,MAX[0,wealth(t)]

3. Wealth and motivation rules

A *Pre-migration-Migrant's* relative **average nuclear family wealth** can affect their **motivation** to migrate. A global parameter used in this rule is: ***wealthMotivationChange = 0.01***

3a. Relative average nuclear family wealth rule. Every time-step, **average nuclear family wealth** is compared to all families in the home sub-area to determine relative wealth.

3b. Wealth and motivation rule. If a *Planning-Migrant's* **average nuclear family wealth** compared to all **average nuclear families' wealth** in their **home** sub-area, is in the lowest 40% or within the 60-80% range then there is no change to **motivation**. If their **average nuclear family wealth** is in the 20-60% range their **motivation** increases IF their migration **motivation threshold** is already equal to or lower than 0.8. If a *Planning-Migrant's* **average nuclear family wealth** is in the top 20% their **motivation** decreases till a certain point. In short:

<40%	40-60%	60-80%	80-100%
no change	Increase motivation (IF threshold ≤ 0.8)	no change	Decrease motivation

3c. Motivation constraint. Motivation is constrained so it cannot be less than 0 or exceed 0.99.

Rationale: Evidence on the relationship between poverty and international labour migration indicates that low-middle income households are most incentivised by the international wage differences (306, 307). The Myanmar Living Condition survey reports that, *"economic migration abroad is higher among the non-poor, while the poor are more likely to be temporary economic migrants working within Myanmar. . . . Only those who can afford these costs and who deem temporary migration abroad to be profitable may decide to follow this route."* (260) Relatively 'high' income households are less incentivised to migrate for low wage international work, although they might migrate for education or specialised roles outside of the scope of this ABM. Thus, high wealth households experience a decreased motivation to migrate. Labour and development economist Oded Stark theorised that relative wealth, not always absolute wealth, is a strong influence on motivation to migrate (308). This theory has been supported by empirical evidence, including the MMSNA study informing this ABM, which reported that many respondents described 'financial aspirations' in relation to other households or peer groups, for example, wanting to be 'better off' or have a new house like other return migrants (215).

Finally, household financial motivations to migrate often fall on select family members. The Myanmar Living Conditions survey reports an increasing likelihood to migrate age 15-20 that then steadily decreases for ages of 25-60 (260). In Myanmar, it is most often the young adults and historically the men that migrate abroad for work (81). This rule uses the migration 'threshold' as a proxy for demographic propensity to migrate and excludes migrants with high thresholds from a household wealth influenced motivation change.

3a. Relative average nuclear family wealth rule

For each home sub-area:
Create a temporary array called *subAreaWealths* that will hold all *averageNuclearFamilyWealth* referenced to their *nuclearFamilyID*.

For each family:
averageNuclearFamilyWealth = sum of wealth of nuclearFamily agents/total nuclearFamily agents
add averageNuclearFamilyWealth to subAreaWealths array for their home sub-area

For each sub-area:
sort nuclearFamilyIDs in subAreaWealths array in ascending order by their averageNuclearFamilyWealth

3b. Wealth and motivation rule

IF *averageNuclearFamilyWealth < 40% of families in home subAreaWealths*
THEN
    no change to motivation

ELSE IF *averageNuclearFamilyWealth > 60% AND < 80% of families in home subAreaWealths*
THEN
    no change to motivation

ELSE IF *averageNuclearFamilyWealth ≥ 40%* AND *≤ 60% of families in home subAreaWealths*
THEN
    IF *motivationThreshold ≤ 0.8*
    THEN
        motivation(t) = motivation(t-1) + wealthMotivationChange
    ELSE
        no change to motivation
    END

ELSE IF *averageNuclearFamilyWealth > 80% of families in home subAreaWealths*
THEN
    motivation(t) = motivation(t-1) - wealthMotivationChange
END

	3c. Motivation constraint: *motivation(t)* = MIN[0.99,MAX[0,*motivation(t)*]]
4. Influence and motivation rules A *Pre-migration-Migrant's* incoming social **influences** can affect their **motivation** to migrate. Two global parameters used in this rule is: ***influenceMotivationChange = 0.001*** ***influenceThreshold = 0.25*** **4a. Weighted average influence rule.** Every time-step, a *Pre-migration-Migrant* receives **influences** from extended family *Migrants* (in all locations) and non-family *Migrants* within their **vision**. All incoming influences are used to find a **weighted average influence**. **Influence** from family *Migrants* and *Migrants* with at least one completed migration are given double weighting. **4b. Influence and motivation rule.** If the **average weighted influence** is a certain amount higher or lower than current **motivation,** then **motivation** increases or decreases, respectively. If motivation changes, then the **motivation constraint** (Rule 3c above) is executed. N.B. Motivation(t) may have already been updated in Rule 3. This additional change to motivation(t) would add to that change does not overwrite that change. For within-rule clarity, we use (t) and (t-1) to refer to an update to current motivation (t) using the most recent value for motivation (t-1). **Rationale:** The MMSNA study highlights the range of social network interactions (encouragements, discouragements, expectations, behaviour modelling, etc) that influence motivations to migrate (215). The most influential exchanges described were often between prospective migrants and their family or 'returnee' migrants in their communities. Therefore, the influence of those agents have been double weighted. Individual migrants sometimes responded to these influences differently (e.g., 'I *had* to come because my husband made me' versus 'My mother did not want me to come but I made my *own* decision') (215). Given these anecdotal accounts of heterogenous responses to social influences, the social influence rule is probabilistic. The MMSNA study and other studies we are aware of, do not offer quantitative distributions of these varied responses so for this first model we have resigned to make it equally likely for a migrant's motivation to be influenced or not.	**4a. Weighted average influence rule** *weightedTotalInfluence = (sum influence of extended family Migrants)*2 +* *(sum influence of Migrants in vision with completed migrations ≥ 1)*2 +* *(sum influence of Migrants in vision with completed migrations = 0)*1* *totalInfluencers = (total extended family Migrants whose influence was counted)*2 +* *(total Migrants with completed migrations ≥ 1 whose influence was counted)*2 +* *(total Migrants with completed migrations = 0)*1* *weightedAverageInfluence = weightedTotalInfluence/totalInfluencers* **4b. Influence and motivation rule** IF *weightedAverageInfluence > motivation(t-1) + influenceThreshold* THEN *motivation(t) = motivation (t-1) + influenceMotivationChange with probability = 0.5* *no change to motivation(t) with probability = 0.5* ELSE IF *weightedAverageInfluence < motivation(t-1) - influenceThreshold* THEN *motivation(t) = motivation (t-1) - influenceMotivationChange with probability = 0.5* *no change to motivation(t) with probability = 0.5* ELSE *no change to motivation(t)* END **Motivation constraint rule** (Rule 3c)

5. Unsolicited offers rules

5a. Receive unsolicited offer rule. Agents that make a direct **offer** to a *Migrant* are added to the **planning network**. At this stage, an **offer** can be made to a *Pre-migration-Migrant* by an *Employed-Migrant* in their extended family member or a *Recruiter* or *Facilitator* within their **vision**. Any offer, in any Sub-Model stage of the ABM, might also include links (through the agent making the **offer**) to other agents which then presents the option for a **'combined offer'**. See Rule 25b and Rule 29 for the corresponding offer rules.

5b. Review unsolicited family offer rule. Any unsolicited **offers** (and associated **combined** offers) from an *Employed-Migrant* are reviewed first. A **combined offer** from an *Employed-Migrant* uses the agent IDs in that *Migrant's* **migration network** (i.e., any *Intermediary* they used for their own **migration**). If the *Pre-migration-Migrant's* **motivation** is already within 0.1 of their **motivation threshold**, then they identify the **best offer** based on their **preference**.

5c. Review unsolicited Intermediary offer rule. If the *Migrant* has not received any family **offers**, or they did not identify a **best offer** from those received, then they repeat a similar set of rules to review unsolicited *Intermediary* **offers** and **combined offers**.

Rationale: The MMSNA identified three categories to describe how migrants decided to migrate (i.e., the point that the migration was initiated) using the structured data on network actors involved in the decision to migrate and qualitative data on the process of deciding to migrate. The three categories include: 1) accepting an unsolicited opportunity to migrate presented by a close social tie, usually family; 2) accepting an unsolicited opportunity to migrate presented by an intermediary actor, usually a 'facilitator' or 'recruiter'; or 3) being motivated 'enough' to start planning to migrate irrespective of any known opportunity to migrate. This rule incorporates the first two options (Rule 7 addresses the third)/ Opportunities to migrate are framed as 'offers' to migrate. In this 'pre-migration' state, when migrants are not actively seeking out migration plans, the offer selection process gives priority to family offers as this was how the majority (50%+) of migrations were initiated in the MMSNA study, which confirmed other research in the Myanmar-Thailand corridor that socially mediated migrations are the most common pathway for Myanmar migrants (82, 91). The MMSNA qualitative narratives indicated that most migrants accepting these unsolicited opportunities had pre-existing motivation or interest to migrate, so this rule includes a motivation condition. A migrant's motivation must already be within a certain range from their threshold to consider accepting an unsolicited offer. This condition range is smaller for accepting an intermediary offer compared to a family offer – again to recognise the increased use of and trust in family facilitated migration (91, 215).

Separate from the 'global'[1] preference for a family offer, every migrant also has a 'preference' (e.g., preference to work in a factory or hospitality) used as a possible decision condition at multiple points in the model. These preferences were identified thematically in the MMSNA qualitative analysis and concurred with the migration decision influences reported by the CHIME study survey data that

5a. Receive unsolicited offer rule

IF *unsolicited offer received*
THEN
    planningNetworkSize(t) = planningNetworkSize(t-1) + total agents offering
    planningNetwork(t, planningNetworkSize(t)) = id of agent(s) offering
    Review unsolicited family offer rule (Rule 5b)
ELSE
    Migration motivation decision (Rule 7)
END

5b. Review unsolicited family offer rule

IF *family offer received* AND *motivation(t) > motivationThreshold - 0.10*
THEN
    IF *any offer satisfies preference*
    THEN
        randomly select bestOffer
    ELSE
        randomly select bestOffer with (probability = 0.4)
        do not select bestOffer with (probability =0.6)
    END
ELSE
    Review unsolicited Intermediary offer rule (Rule 5c)
END

5c. Review unsolicited Intermediary offer rule

IF *intermediary offer received* AND *motivation(t) > motivationThreshold - 0.05*
THEN
    IF *any offer satisfies preference*
    THEN
        randomly select bestOffer
    ELSE
        randomly select bestOffer with (probability = 0.2)
        do not select bestOffer with (probability =0.8)
    END
ELSE
    Migration motivation decision (Rule 7)
END

informed the baseline models distribution of these preferences in the migrant population (81, 215). See full description of migrant 'preferences' in *Section A.7.2 – Agent entities* of this document. [1] 'Global' meaning a parameter or rule condition set for the whole model, irrespective of agent attributes, not referencing the literal 'world'.	
6. Unsolicited offer decision If the *Pre-migration-Migrant* identified a **best offer** (Rule 5), then they decide whether to accept that **best offer**. A global parameter used in this rule is: ***increasedInfluenceRate*** *= 1.1* **6a. Unsolicited offer decision.** If a **best offer** was identified from the unsolicited offers, then the *Migrant* accepts the offer 90% of the time. If they accept the offer, they add agent(s) 'offering' (including any **combined offer** links) to their **migration network**, update their **state** to 'planning', add a new **migration** to their **migrations** array, update the **plan** properties in that **migration** to match the properties of the **offer** they have accepted, and update their **influence**. If they do not accept the **best offer,** then there is no change **6b. Influence constraint.** Influence is constrained so it cannot be less than 0 or more than 1. **Rationale:** Once an offer is made and Migrant have met their motivation threshold, preference, and employer conditions it is assumed that any remaining offer is highly suitable to the Migrant and they would accept in most cases, subject to some probability that they might decline in case they changed their mind or some other obstacle to their migration arose. This latter option is not represented in the empirical data because of the sampling approach which was only with migrants that were in Thailand and thus had completed migration. However, for this model we did not assume that all migrants do continue through migration at each stage and thus there is always a small probability of 'drop out' for unspecified reasons in the model. Migrants that decide to migrate have an increased influence on other Migrants. This assumption is informed by the empirical analysis as many migrants named other community members planning or returning from migration as strong influences on their own decision is that migrants planning to migrate can have an indirect or direct effect on others in their home area that see they are planning to migrate and might discuss these plans with them or just observe from afar and be more inclined to also migrate.	**6. Unsolicited offer decision** IF *bestOffer* ≠ empty THEN *accept offer with probability = 0.9* *migrationNetworkSize(t) = migrationNetworkSize(t-1) + total agent(s) making offer* *migrationNetwork(t, migrationNetworkSize (t)) = id of agent(s) making offer* *state(t) = planning* *add new migration to migrations array and give it empty properties including 'plan'* *plan(t) properties are populated by the accepted offer properties* *influence(t) = influence(t-1) * increasedInfluenceRate* **6b. Influence constraint:** *influence(t) =* MIN[1,MAX[0,*influence(t)*]] *reject offer with probability = 0.1* *no change to migrationNetwork, migrations, or state* ELSE **Migration motivation decision** (Rule 7) END

Migration motivation decision A global parameter used in this rule is: ***increasedInfluenceRate*** *= 1.1* If the *Pre-migration-Migrant* did not identify a **best offer** (Rule 5) or did not accept a **best offer** (Rule 6), then they decide if they are motivated 'enough' to migrate anyway. If a *Migrant's* **motivation** to migrate is equal to or greater than their **motivation threshold** then they decide to migrate, update their **state** to 'planning', add a new **migration** to their **migrations** array, and update their **influence**. Otherwise, there is no change. **Rationale:** This rule models the third category of migration 'initiation' – being motivated 'enough' to migrate irrespective of any known or accepted offers, as described in Rule 5. These represent the cases in the MMSNA where individuals said their *final* decision was made completely independently of any other actors in their network (215). Their 'high' motivation was often a result of positive social influences and/or financial incentives/pressures to increase, all of which are socially embedded in the model, but their decision was independent of any known connections to destination or work. This probabilistic rule accounts for the possibility that a migrant could encounter a range of barriers (e.g., family bans the idea to migrate, physically unable, etc.) despite being motivated enough to migrate, these cases were not in our sample due to the sampling method, but the model assumes different points of 'drop out' throughout the model.	**7. Migration motivation decision** IF *motivation(t) ≥ motivationThreshold(t)* THEN *state(t) = planning with (probability = 0.9)* *add new migration to migrations array and give it empty properties including 'plan'* *influence(t) = influence(t-1) * increasedInfluenceRate* **Influence constraint** (Rule 6b) *no change to state(t) or influence(t) with (probability = 0.1)* ELSE *no change to state(t), migrations, or influence(t)* END End time-step

Sub-Model 2 – Planning

Narrative Overview

The primary agent that executes the process in Sub-Model 2 (see Figure 60 and Table 54) is a *Planning-Migrant* whose primary goal is to have at least a partial migration **plan** and to leave **home**.

A *Planning-Migrant's* actions and decisions depend partly on how they decided to migrate in Sub-Model 1 (i.e., they accepted an unsolicited **offer** OR they were **motivated** 'enough' without an offer). An accepted unsolicited **offer** populates a *Migrant's* **plan** properties before they enter Sub-Model 2 whereas motivated without an offer does not populate **plan** properties in Sub-Model 1. Sub-Model 2 is divided into **2-A** and **2-B** to account for this distinction (see Figure 60).

The final decision in Sub-Model 2 is whether to leave **home** or discontinue their **migration**. A *Planning-Migrant* must have a **destination plan** to leave home. In Sub-Model 2, a migration **plan** can be populated by:

a) accepting an unsolicited or solicited **offer** from an *Employed-Migrant* in their **family**;
b) accepting a solicited **offer** from an *Intermediary* within their **vision**; and/or
c) deciding aspects of their migration **plan** independent from **offers**.

Unlike Sub-Model 1, in which all relevant steps are executed in a single time-step and repeated in the next time-step, in Sub-Model 2 only certain steps are executed in each time-step and the duration of Sub-Model 2 depends on where a *Migrant* starts Sub-Model 2, interactions, offers, and decisions. If a *Planning-Migrant* decides to leave they update their **state** to 'transit', but if they decide not to leave their **state** reverts to 'pre-migration'. A *Transit-Migrant* starts the next time-step in Sub-Model 3. A newly 'reverted' *Pre-migration-Migrant* walks **home**, decreases their **motivation** to migrate, and starts the next time-step back in Sub-Model 1.

Figure 60 depicts the Sub-Model 2 process annotated with the rule numbers that correspond to Table 54. Table 54 presents the Sub-Model 2 *Planning-Migrant* agent rules in the order they are executed. Again, like Table 53, it is implicit in Table 54 rules that a *Migrant* agent's **state** is 'planning'.

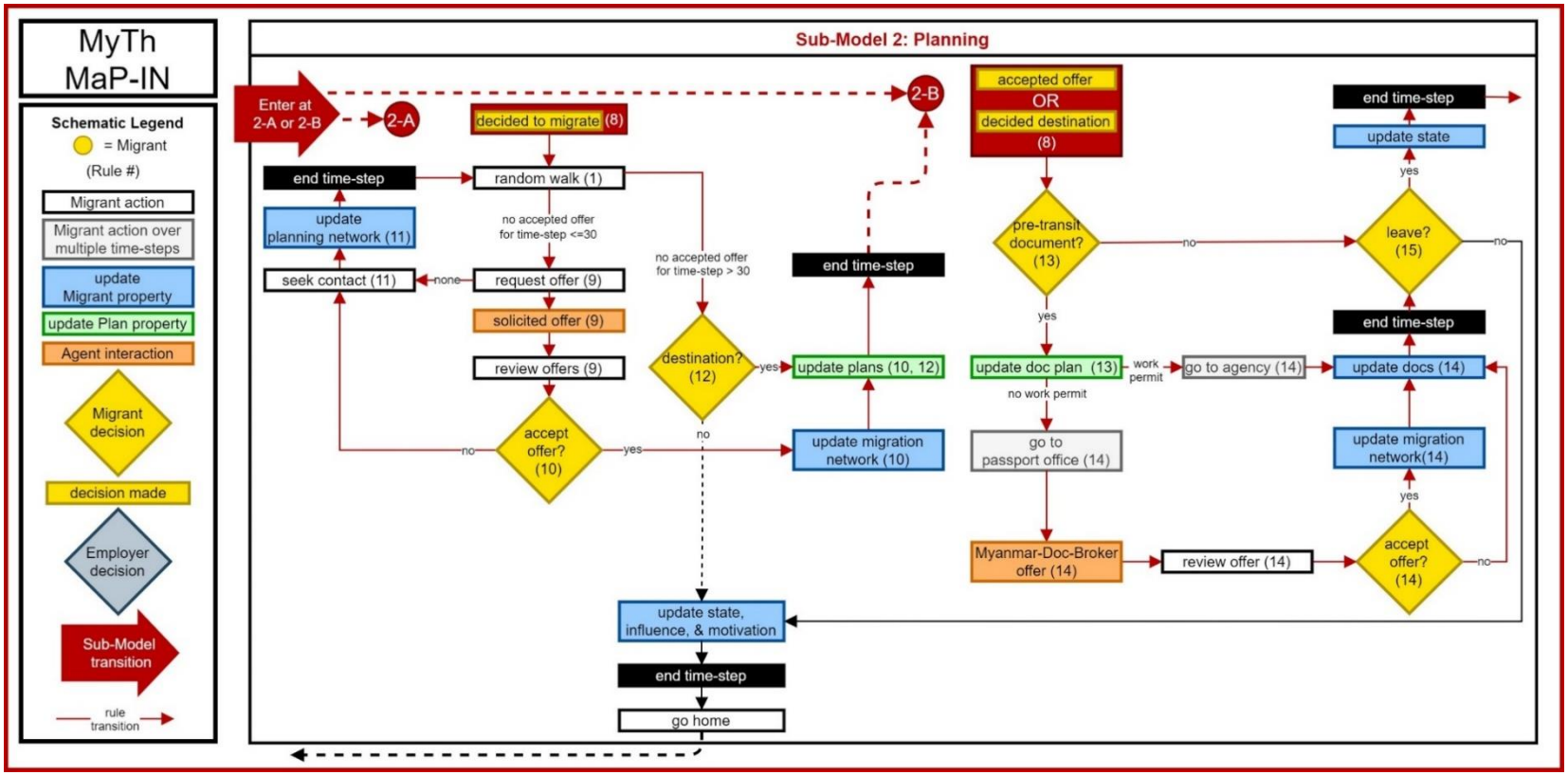


Figure 60. MyTh MaP-IN Sub-Model 2 schematic

Table 54. Sub-Model 2 rules

Rule description, rationale and calibration informed by McAlpine et. al.'s Myanmar-Thailand MMSNA study (215), University of Sussex's CHIME study (81), and the Myanmar Living Conditions survey (260).	**Model based rule** (IF-THEN or basic equation)
8. Sub-Model 2 starting place rule A *Planning-Migrant* starts Sub-Model 2 at either '2-A' or '2-B' depending on whether they have already accepted an **offer** (i.e., **migrationNetwork** ≥ 1). A *Migrant* without an accepted **offer** random walks and starts the 2-A process (Rule 9). A *Migrant* with an accepted **offer** starts the 2-B process (Rule 13). **Rationale**: The MMSNA study found that there is a pathway dependency between migration initiation and planning steps (215). *Migrants* that decided to migrate based solely on their motivation then sought out migration options from their known networks and surrounding community, whereas migrants that decided to migrate by accepting an offer now had plans already in place without needing to 'shop around' in the same way. Sub-Model 2-A and 2-B represent these two forks in the early planning stage based on initiation, again which was informed by the MMSNA structured data.	**8. Sub-Model 2 starting place rule** IF *migrationNetwork(t) is empty* THEN **Random walk rule** (Rule 1) *start Sub-Model 2-A* - **Solicited offer rules** (Rule 9) ELSE *no movement* *start Sub-Model 2-B* - **Pre-transit documentation decision** (Rule 13) END

9. Solicited offer rule

A *Planning-Migrant* without an accepted **offer** requests offers, possibly receives offers, and then review offers to identify a **best offer**. Rule 9 is a slightly extended and adapted version of Rule 5.

9a. Request offers rule. A *Planning-Migrant* can spend up to 30 time-steps requesting **offers** from their **planning network** (dynamic array of agents). After 30-time-steps without an accepted **offer** they must decide their destination. See request response rules in Rule 24b and Rule 30.

9b. Receive solicited offers rule. If any solicited **offer(s)** are received, the *Migrant* reviews the **offer(s).** If no **offer** is received, they 'seek new contacts' for their **planning network**.

9c. Review solicited offers rule. If only one solicited **offer** (with no **combined offer**) is received, this is, in effect, the **best offer.** If more than one **offer** is received, the *Migrant* identifies the **best offer** based on their **preference**. If none of the **offer(s)** satisfy their **preference,** then they randomly select a **best offer** 50% of the time. If they do not select a best offer, then they seek contacts (Rule 11) to be able to ask for more **offers** in the next time-step.

Rationale: The MMSNA study reports that individuals that had decided to migrate but did not yet have plans on where to go or work would look for migration advice or 'leads' in whatever convenient networks of contacts they were already aware of (planning network) or new contacts they would make, such as extended family abroad, returned migrants at home, or intermediaries working nearby (215). Often these connections were made before leaving home, but in some rarer cases, a migrant would leave home without any assisted plans. After one month of exhausting possible leads a *Planning-Migrant* in the model has the option to choose their own destination. The choice of a one-month threshold is an estimate based on empirical evidence that it takes most migrants a few weeks up to a few months to complete migration. Assuming some of this time has already passed in the decision process and more time is needed to complete the migration, we have chosen one-moth for this seeking contact phase. This temporal condition is not informed directly by the empirical MMSNA since we did not capture on average how long migrants attempted to find contacts and assume that, in reality, it is likely to be a range of time migrants take to complete this process before deciding to move on independently.

9a. Request offers rule

IF *durationPlanning(t) ≤ 30*
THEN
    request offer from planningNetwork(t)
    Receive solicited offers rule (Rule 9b)
ELSE
    do not request offer from planningNetwork(t)
    Destination decision (Rule 12b)
END

9b. Receive solicited offers rule

IF *solicited offer(s) received*
THEN
    Review solicited offers rule (Rule 9c)
ELSE
    Seek contacts rule (Rule 11)
END

9c. Review solicited offers rule

IF *solicited offer(s) received*
THEN
    IF *any offer satisfies preference*
    THEN
        randomly select bestOffer
        Accept best solicited offer decision (Rule 10)
    ELSE
        randomly select bestOffer with probability = 0.5
        Seek contacts rule (Rule 11) *with probability = 0.5*
    END
ELSE
    Seek contacts rule (Rule 11)
END

10. Accept best solicited offer decision If the *Planning-Migrant* has identified a **best offer** from their solicited offers, they accept the **offer** 90% of the time. If they accept the offer, they add the agent making the offer to their **migration network** and update the **plan** properties in that **migration** to match the **offer** properties they have accepted. If they do not accept the **best offer**, then there is no change, and they seek new contacts. **Rationale:** This rule assumes that by this stage, most migrants have considered this option, and alternatives, enough to warrant them to accept or else they would not still be considering the offer. As other rules in this ABM have done, this rule leaves a probabilistic potential to 'reject' for any range of reasons not represented in the data as these interviews were beyond the scope of our sampling frame.	**10. Accept best solicited offer decision** IF *bestOffer* ≠ empty THEN *accept offer with probability = 0.95* *migrationNetworkSize(t) = migrationNetworkSize(t-1) + total agent(s) offering* *migrationNetwork(t, migrationNetworkSize (t)) = agent id(s) offering* *plan(t) properties are populated by accepted offer properties* *reject offer with probability = 0.05* *no change to migrationNetwork(t) or plan(t)* **Seek contacts rule** (Rule 11) ELSE *no change to migrationNetwork(t) or plan(t)* **Seek contacts rule** (Rule 11) END End time-step

11. Seek contacts rule

If a *Planning-Migrant* did not receive any **offers** or rejected their **best offer,** then they try to add new agents ('contacts') to their **planning network** in preparation for the next time-step. A *Planning-Migrant* adds all agents that meet the criteria of any of these groups:

1. *Employed-Migrant* in **extended family**;
2. *Intermediary* from a returnee *Migrant's* **planning network** if 'returnee' is within **vision**; or
3. *Intermediary* within expanded **vision** (vision x2).

This rule creates a temporary '**new contacts**' array to store these agent IDs temporarily before adding them all to the *Planning-Migrant's* **planning network.**

Rationale: The MMSNA structured network data indicates that social contacts that had migrated previously, especially family, and intermediaries through social networks were key sources of migration information, advice, and services at the early planning stages (215). Future iterations will also consider the influence of 'weak ties'.

11. Seek contacts rule

newContactsSize = 0
newContacts = empty

IF *bestOffer* = empty OR *bestOffer rejected*
THEN

IF *extended family agent's state = employed*
THEN
newContactsSize = total agents that meet the conditions
add id of agent(s) that meet the conditions to newContacts array
ELSE
no change to newContactsSize or newContacts
END

IF *Migrant within vision with (completed migrations > 0)*
THEN
newContactsSize is increased by total intermediaries in that Migrant's planningNetwork(t)
add id of intermediaries to the newContacts array
ELSE
no change to newContactsSize or newContacts
END

IF *Intermediary is within expanded vison*
THEN
newContactsSize is increased by total agents that meet the conditions
add id of agent(s) that meet the conditions to newContacts array
ELSE
no change to newContactsSize or newContacts
END

planningNetworkSize(t) = planningNetworkSize(t-1) + newContactsSize
planningNetwork(t, planningNetworkSize(t)) = id(s) in newContacts array

END
End time step

12. Destination decision

If a *Planning-Migrant* has not accepted an **offer** for more than 30 time-steps, they must decide whether to continue planning and choose a **destination** or whether to return **home**.

A global parameter used in this rule: ***decreasedMotivationRate= 0.9***

12a. Continue planning decision. A *Planning-Migrant* without an accepted **offer** has a 10% chance of deciding to discontinue migration, updating their **state** to 'pre-migration', updating their **motivation** to be slightly less than their initialised **motivation**, and, finally, they deactivate the current **migration** in their **migrations** array.

12b. Destination decision. If a *Planning-Migrant* decides to continue their **migration,** they then decide their **destination plan** based on their **preference**.

Rationale: The MMSNA and CHIME study findings on the influences on migration decision making reported that multiple factors (formalised as 'preferences' in the MyTh MaP-IN ABM) influenced migration decision making, including the destination decision (81, 215).

12a. Continue planning decision

IF *durationPlanning(t) > 30* AND *no offer has been accepted*
THEN
state(t) = pre-migration with (probability = 0.10)
motivation(t) = initial motivate decreasedMotivationRate*
Motivation constraint (Rule 3c)
deactivate current migration

state(t) = planning with (probability = 0.90)
no change to state(t), motivation(t), or migration
Destination decision (Rule 12b)
END

12b. Destination decision

IF *decided to continue planning*
THEN
IF *preference = social*
THEN
planDestination(t) = destination with the most home migrants
END

IF *preference = family*
THEN
planDestination(t) = destination with any family
END

IF *preference = sector* OR *wage*
THEN
planDestination(t) = 'bangkok'
END

IF *preference = proximity*
THEN
planDestination(t) = 'mae sot'
END

IF *preference = intermediary* OR *work* OR *fees* OR *legal*
THEN
planDestination(t) = 'mae sot' with (probability = 0.4)
planDestination(t) = 'bangkok' with (probability = 0.4)

	planDestination(t) = 'phang nga' with (probability = 0.2) END END End time step
Sub-Model 2-B begins here	
13. Pre-transit documentation decision **13a. Pre-transit documentation decision.** A *Planning-Migrant* without a **documentation plan** decides whether to get a passport or work permit *before* entering Thailand. **13b. Find Recruiter rule.** If a *Migrant* decides they want a work permit but does not have a *Recruiter* in their **migration network,** then they randomly select a *Recruiter*. **Rationale:** In accordance with Thailand's immigration law, labour migrants must enter Thailand with the appropriate identity and work document (typically a passport and work permit). The MMSNA (215), and other research in the Myanmar-Thailand corridor (81, 91), indicates that there are many different combinations of documents migrants may acquire at various stages of migration, including attempts to secure a passport and possibly a work permit (conditional on having a passport) before entering Thailand. In the legal migration channel (i.e., 'MOU' migration), recruitment agencies are the gatekeepers that process work permits (91). Individuals can choose to get passports on their own through the passport offices or can receive help from agencies in the passport application process before securing their work permit. In the MMSNA, some migrants expressed having a preference to migrate with some form of documentation (e.g., a passport or border pass – the latter addressed in future rules) or the 'MOU' way (passport *and* work permit) specifically. Overwhelmingly, according to the CHIME study and ILO reports on Myanmar-Thailand migration, the majority of Myanmar migrants still migrate to Thailand without any long term documentation (81, 82). Thus, this rule only assigns these pre-migration documentation plans (passport, work permit) to migrants with a preference for legal migration, otherwise the documentation plan stays empty currently.	**13a. Pre-transit documentation decision** IF *planDocumentation(t)* = empty THEN IF *preference = legal* THEN *planDocumentation(t) includes 'passport' with (probability = 0.15)* *planDocumentation(t) = 'passport' AND 'work permit' with (probability = 0.15)* *planDocumentation(t) stays empty with (probability = 0.7)* ELSE *planDocumentation(t) stays empty* END END **13b. Find Recruiter rule** IF *planDocumentation(t) includes 'work permit'* THEN IF *migrationNetwork does not include a Recruiter* THEN *randomly select recruiter id to add to migrationNetwork array* *accept offer* *populate plan(t) with recruiter offer* END END

14. Get pre-transit documentation rules

Planning-Migrants that have decided to get a passport need to go to either Magway or Yangon.

14a. Go to Magway or Yangon rule. If the *Planning-Migrant* only needs a passport and is in Rakhine or Magway they will go to the Magway passport office, but if they are in Bago or Yangon they will go to the Yangon passport office. If the *Migrant* needs a passport and a work permit, then they must go to Yangon.

14b. Respond to Myanmar-Doc-Broker offer. If a *Planning-Migrant* receives an unsolicited **offer** from a *Myanmar-Doc-Broker* to help with the passport application then they decide whether to accept the **offer** based on their current **wealth**, other **offers**, and **documentation plan**. See the Myanmar-Doc-Broker offer rule in Rule 31.

14c. Get Documents rule. Once a *Planning-Migrant* arrives at the passport office or recruiter agency and the processing time-steps have passed, they then get their documents. If a *Recruiter* or *Myanmar-Doc-Broker* is arranging the process then the *Migrant* always gets their documents, but if the *Migrant* is trying to get their passport alone there is a 25% chance, they fail to get their passport. Either way, using a Myanmar-Doc-Broker speeds up the process for *Migrants*. If a Migrant fails to get a passport, they still decide whether or not they will leave (Rule 15).

Rationale: A *Migrant* planning to get a work permit before migrating has to Yangon to complete the recruitment process. A *Migrant* that is only getting a passport can do this in major urban areas (Yangon or Magway in the model) and the model rule assumes that the *Migrant* will choose to go to whichever passport office is closest to their home area. Some of the qualitative narratives and network maps from the MMSNA described Myanmar based document brokers (unlicensed actors) that would work in the nearby vicinity of the passport offices to try and offer administrative support to individuals trying to apply for a passport in exchange for a fee. Migrants that chose to use these services explained that the process was too complicated or confusing for them to do alone and they preferred to pay to be sure they got the document and as quickly as possible (215). Because the fees paid to these agents were usually required up front (in cash) the rule includes a condition that the migrant has the available wealth on hand to cover the cost of the Myanmar-Doc-Broker's fees. These brokers were described by some respondents as essential service providers to ensure their passport application process was smooth, as quick as possible, and successful (215). The rule reflects an increased likelihood of success and speed for migrants that paid for extra administrative support from Myanmar-Doc-Brokers. The time-steps reflect the average processing time for these processes according to recent Verité led research on the MOU and other documentation processes (91).

14a. Go to Magway or Yangon rule

```
IF planDocumentation(t) includes 'passport'
THEN
        IF planDocumentation(t) includes 'work permit'
        THEN
                IF migrationNetwork(t) includes Recruiter
                THEN
                        Go to Recruiter's agency
                END
        ELSE
                IF home = Rakhine OR Magway
                THEN
                        Go to Magway passport office
                ELSE
                        Go to Yangon passport office
                END
        END
ELSE
        Leave decision (Rule 14)
END
```

14b. Respond to Myanmar-Doc-Broker offer

```
IF offer received from Myanmar-Doc-Broker AND documentation(t) =
empty
THEN
        IF migrationNetwork(t) does not include a Myanmar-Doc-Broker
        OR Recruiter
        THEN
                IF Myanmar-Doc-Broker fees < wealth(t)
                THEN
                        IF planDocumentation(t) = passport
                        THEN
                                accept offer with (probability =
                                0.75)
                                        migrationNetworkSize(t)
                                        =
                                        migrationNetworkSize(t-
                                        1) + 1
                                        migrationNetwork(t,
                                        migrationNetworkSize
                                        (t)) Myanmar-Doc-
                                        Broker's id
```

	reject offer with (probability = 0.25) ELSE *No change* END END END END **14c. Get documents rule** IF *at passport office* THEN IF *migrationNetwork(t) includes Myanmar-Doc-Broker* THEN *after 10 time-steps get passport* *documentationSize(t) = documentationSize(t-1) + 1* *documentation(t, documentationSize (t)) = passport* ELSE *after 17 time-steps get passport with (probability = 0.75)* *documentationSize(t) = documentationSize(t-1) + 1* *documentation(t, documentationSize (t)) = passport* *fail to get passport with (probability = 0.25)* *planDocumentation(t) = border pass* END ELSE **Leave decision** (Rule 15) END IF *at Recruiter agency* THEN *after 50 time-steps get passport* AND *work permit* *documentationSize(t) = documentationSize(t-1) + 2* *documentation(t, documentationSize (t)) = passport* AND *work permit* **Leave decision** (Rule 15) END

15. Leave decision A *Planning-Migrant* must make a final decision at the end of Sub-Model 2-B whether they want to leave. This is a probabilistic rule based partially on the **documentation** they have acquired. If they decide not to leave, they walk **home** (pausing all other functions till they arrive home), update **state** to 'pre-migration', update **motivation** slightly decreased value of initialised **motivation** (and constrain motivation)**,** and, finally, they deactivate the most recent **migration** in their **migrations** array. **Rationale:** Like the end of Sub-Model 1, the assumption in this rule is that migrants that have made it through the process up till this point are more likely to continue than not. Migrants that have gone through the process and paid the cost for a passport and migrants that have a known employment option at destination are 15% more likely than migrants without a passport or employer plan to continue their migration.	**15. Leave decision** IF *documentation(t) includes passport* THEN *decide to leave with (probability = 0.95)* *decide not to leave with (probability = 0.05)* ELSE IF *planEmployer(t)* ≠ empty THEN *decide to leave with (probability = 0.95)* *decide not to leave with (probability = 0.05)* ELSE *decide to leave with (probability = 0.8)* *decide not to leave with (probability = 0.2)* END END IF *decides to leave* THEN *state(t) = transit* ELSE *walk home and pause all other function while walking home* *when at home state(t) = pre-migration* *deactivate most recent migration in the migrations array* *motivation(t) = initial motivation - 0.1* **Motivation constraint** (Rule 3c) END End time step

Sub-Model 3 – Transit

Narrative Overview

The primary agent that executes the process in Sub-Model 3 (see Figure 61 and Table 55) is a *Transit-Migrant*. A *Transit-Migrant's* goal is to arrive at their planned **destination** and to be offered **employment**. A *Transit-Migrant's* actions and decisions depend partly on any **offers** they have accepted, their **destination plan**, and their **preference**. Like Sub-Model 2, only certain steps are executed in each time-step and the whole process length depends on the time it takes to coordinate a **transport plan**, meet the conditions for departure, transit to **destination**, and find **employment**.

A *Transit-Migrant* makes a **transport** decision in this Sub-Model, but the final decision in this sub-model is made by the *Employer.* The *Employer* decides whether to **offer employment** in response to a *Transit-Migrant's* request. If a *Transit-Migrant* is offered employment then their **state** is updated to 'employed', but if they are not offered employment for over 100 time-steps then their **state** reverts to 'pre-migration'. An *Employed-Migrant* starts the next time-step in Sub-Model 4. A newly 'reverted' *Pre-migration-Migrant* walks **home**, decreases their **motivation**, and starts the next time-step back in Sub-Model 1.

Figure 61 depicts the Sub-Model 2 process annotated with the rule numbers that correspond to Table 55. Table 55 presents the Sub-Model 3 *Transit-Migrant* rules in the order they are executed. Again, like the previous sub-models, it is implicit in the Table 55 rules that a *Migrant's* **state** is 'transit'.

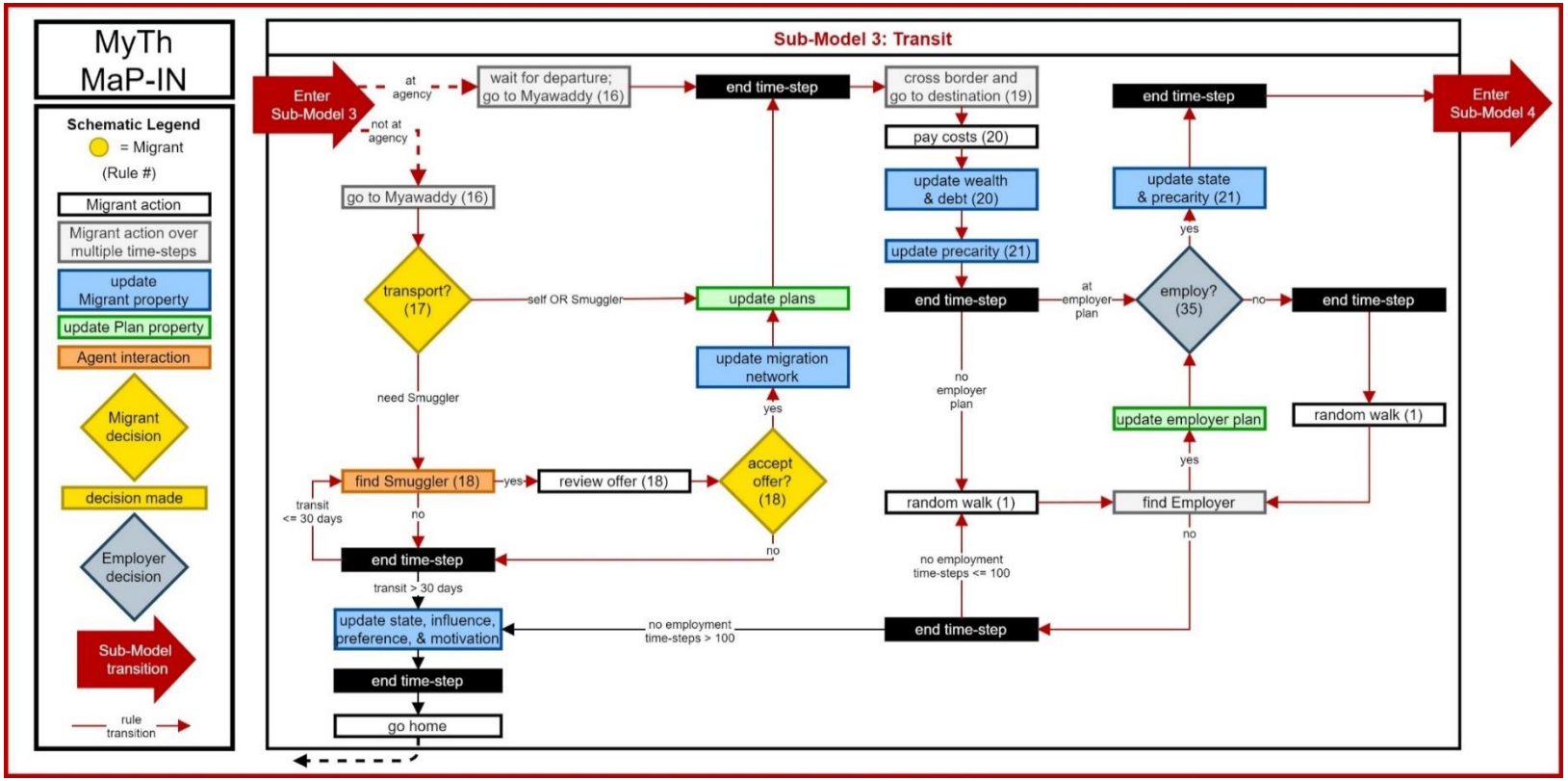


Figure 61. MyTh MaP-IN Sub-Model 3 schematic

Table 55. Sub-Model 3 rules

Rule description, rationale and calibration informed by McAlpine et. al.'s Myanmar-Thailand MMSNA study (215), University of Sussex's CHIME study (81), and the Myanmar Living Conditions survey (260).	**Model based rule** (IF-THEN or basic equation)
16. Go to Myawaddy rule All *Transit-Migrants* start Sub-Model 3 by going to the Myawaddy sub-area (next to the border crossings). A *Migrant* using a *Recruiter* waits at the agency in Yangon until their group of migrants is prompted to leave for Myawaddy. The departure is prompted once the total *Migrants* for a single *Employer* meet the agency's required minimum. See Rule 32. **Rationale:** Recruitment agencies work on *Employer* demand and recruit groups of migrants to transfer to destination and employer at the same time, via Myawaddy (91). Migrants that choose to go the MOU way through recruitment agencies are then subject to both the generic processing wait time (in previous Sub-Model 3) for all agencies and the agency specific wait time while they recruit fellow workers. Whereas migrants travelling outside of the MOU process do not have any delays to going to Myawaddy.	**16. Go to Myawaddy rule** IF *migrationNetwork(t) does not include a Recruiter* THEN IF *location(t) is not in Myawaddy* THEN *walk to Myawaddy* **Transport decision** (Rule 17) END ELSE *wait at agency till prompted to leave* (Intermediary Rule 33a) *walk to Myawaddy* End time step Next time-step: **Border crossing rule** (Rule 19) END

17. Transport decision

A *Transit-Migrant* without a **transport plan** decides whether they will transport with or without a *Smuggler.* The **transport plan** decision depends on the *Migrant's* **destination plan** and whether they have a passport. If they decide to transport without a *Smuggler,* they must also decide which **border crossing** they will use.

Rationale: There are many ways a migrant can cross the very long and porous border between Myanmar and Thailand (215). This model has simplified the border crossing options into three types: 1) unofficial crossing without a smuggler; 2) unofficial crossing with a smuggler; or 3) official crossing at the Thai immigration check-point. The choice to use a smuggler depends on the destination (how far a migrant needs to travel to get there) and their documentation (whether they have the rights to move about freely after crossing the border). Most migrants trying to get to Tak, or Mae Sot would not pay for the services of a smuggler because it is easy to get to these destinations with or without documentation alone. However, a migrant trying to get as far as Bangkok or Phang Nga needs to travel a long distance through multiple document checkpoints (e.g., highway bus stops for passport checks of all bus passengers) and so without a document a migrant would need a smuggler's help.

17. Transport decision

IF *planTransport(t)* = empty
THEN
    IF *planDestination(t) = mae sot* OR *tak*
    THEN
        IF *documentation(t) includes 'passport'*
        THEN
            planTransport(t) = own id
            planBorderCrossing(t) = 'official'
        ELSE
            planTransport(t) = own id
            planBorderCrossing(t) = 'official' with (probability = 0.3)
            planBorderCrossing(t) = 'unoffical1' with (probability = 0.7)
        END
    ELSE
        IF *documentation(t) includes 'passport'*
        THEN
            planTransport(t) = own id with (probability = 0.8)
                planBorderCrossing(t) = 'official' with (probability = 0.7)
                planBorderCrossing(t) = 'unofficial1' with (probability = 0.3)

            planTransport(t) = find smuggler with (probability = 0.2)
            no change to planBorderCrossing(t)
        ELSE
            planTransport(t) = find smuggler
            no change to planBorderCrossing(t)
        END
    END
END

18. Find Smuggler rules

18a. Request Smuggler offer rule. If a *Transit-Migrant* decides to transport with a *Smuggler* and does not currently have a **transport plan,** then they need to find a *Smuggler* in Myawaddy. They look for a *Smuggler* in their **vision** and request an **offer**. *Smugglers* are all located in a specific part of the Myawaddy sub-area near the 'unofficial2' border crossing that Smugglers use to take Migrants to Thailand. *Migrants* looking for a *Smuggler* know that this is the general area to find one. See the Smuggler offer rule in Rule 33.

If a *Transit-Migrant* has not accepted a *Smuggler* **offer** after 30 time-steps in 'transit' **state** they walk **home** (pausing all other functions till they arrive home), update **state** to 'pre-migration', update **motivation** slightly decreased value of initialised **motivation** (and constrain motivation)**,** and, finally, they deactivate the most recent **migration** in their **migrations** array.

18b. Review Smuggler offers rule. If a *Migrant* receives offers from a *Smuggler,* they decide whether to accept the *Smuggler's* **transport** and **border crossing** offer based on whether the *Smuggler's* **destination offer** matches the *Migrant's* **destination plan**. If multiple *Smugglers* meet these criteria in a single time-step the *Migrant* chooses the *Smuggler* with the lowest **fees**. If multiple *Smugglers* meet the lowest **fees** criteria, then the *Migrant* selects one of those *Smugglers* randomly.

Rationale: Because Myawaddy is a border-crossing town there are many smugglers and smuggler networks recruiting passengers in that area. This means that migrants, regardless of their destination plan, should be able to find a smuggler to arrange their transport. For simplicity in the model, all smugglers have been confined to a smaller zone of the Myawaddy area where it is assumed all migrants know to look for smugglers and always prefer lower fees.

18a. Find Smuggler rule

IF *planTransport(t) = findSmuggler*
THEN
    IF *duration since transport decision ≤ 30*
    THEN
        walk to Smuggler zone
        Random walk (Rule 1) *within that zone*
        request offer from Smuggler within vision
    END

    IF *duration since transport decision > 30*
    THEN
        walk home and pause all other function while walking home
        when at home state(t) = pre-migration
        motivation(t) = motivation(t-1) – 0.1
        deactivate most recent migration in the migrations array
        Motivation constraint (Rule 3c)
    END
ELSE
    Cross border and go to destination rule (Rule 19)
END

18b. Review Smuggler offers rule

IF *total Smuggler offers received = 1*
THEN
    IF *offerDestination = planDestination(t)*
    THEN
        migrationNetworkSize(t) = migrationNetworkSize(t-1) + 1
        migrationNetwork(t, migrationNetworkSize (t)) = smuggler's id
        planTransport(t) = smuggler's id
        planBorderCrossing(t) = 'unoffical2'
    END

ELSE IF *total Smuggler offers received > 1*
THEN
    IF *offerDestination = planDestination(t)*
    THEN
        filter to offers with lowest fees and randomly select one
        migrationNetworkSize(t) = migrationNetworkSize(t-1) + 1
        migrationNetwork(t, migrationNetworkSize (t)) = smuggler's id
        planTransport(t) = smuggler's id
        planBorderCrossing(t) = 'unoffical2'

	END ELSE *no change to planTransport(t) or planBorderCrossing(t)* END End time step
19. Cross border and go to destination rule **19a. Cross border and go to destination rule.** *Migrants* that are going to be transported by a *Smuggler* need to wait for that agent to prompt them to leave before they can leave Myawaddy. See the Departure rule (Rule 32 in Table 57). *Transit-Migrants* not using a *Smuggler* do not need to wait to leave Myawaddy. The 'waiting' period is the only distinction between the 19a IF/ELSE statement. **19b. Get border pass rule.** Any *Migrant* that goes through the 'official' border crossing without a passport collects a border pass during crossing. **Rationale:** Smugglers, like recruiters, maximise profits by taking groups of migrants to the same destination at one time. Thus, migrants must wait until their chosen smuggler has met their minimum passenger condition (enough to fit in a small number of vehicles and not too many to draw too much attention on illegal routes). Any migrant that is passing through an official immigration checkpoint without a passport needs to acquire a 'border pass'. These are temporary documents that gives migrants the right to enter Thailand (not work) and they are usually valid for 1 week, but migrants can continuously renew them. Each pass costs 100 Thai Baht so any renewal would incur this cost.	**19a. Cross border and go to destination rule** IF *planTransport(t) = smuggler id* THEN *wait till prompted to depart* *go to 'unofficial2' border crossing and cross* IF *planEmployer(t) = empty* THEN *go to planDestination(t) location* ELSE *go to planEmployer(t) location* END ELSE IF *planTransport(t) = own id* OR *recruiter id* THEN *go to planBorderCrossing(t) and cross* IF *planEmployer(t) = empty* THEN *go to planDestination(t) location* ELSE *go to planEmployer(t) location* END **19b. Get border pass rule** IF *borderCrossing(t) = 'official'* AND *documentation(t) does not include 'passport'* THEN *documentationSize(t) =documentationSize(t-1) + 1* *documents(t,documentationSize(t)) = border pass* END

20. Migration costs rules

Key parameter used in this rule:
costDailyTransit *= 0.001 (100 THB)*
costDocTransit *= .01 IF a Migrant went to Yangon/Magway for passport or work permit, otherwise* ***costDocTransit*** *= 0*
costFailedPassport *= .01 IF a Migrant unsuccessfully attempted to get a passport, otherwise* ***costFailedPassport*** *= 0*

20a. Pay migration costs rule. For simplicity's sake in the model, the migration **costs** are summed and paid when a Migrant arrives at **destination** (or **employer** if they are going directly to a planned **employer**). The way these costs are paid (i.e., deducted **wealth**, increased **debt to family**, or increased **debt to industry**) is determined by the wealth the *Migrant* and their family have at the time-step they leave home. The possible applicable **costs**, include:

- Cost of **transit**
- Cost of **documentation**
- Cost of *Intermediary* **fees**

20b. Acquired migration debt rule. Instead of constraining **wealth** and simply 'discarding' and negative value from the agent's **wealth** property (as in Sub-Model 1), **wealth** is still constrained to 0 but any negative **wealth** is assigned to either their **debtFamily** or **debtIndustry** property. After the negative value is moved to debt then wealth is constrained.

20c. Recurring border pass cost. Border pass documents have a randomly set expiration date, but this is a proxy for when a *Migrant* decides to 'stop renewing'. Border passes must be renewed every 7 days and thus this is one migration cost that is recurring and repeats until the document expires or until the *Migrant* decides to return **home**.

Rationale: In the MMSNA analysis, migrants identified family actor network nodes as the individuals who often financed their migrations or that they financed migration by taking on debt to the intermediaries coordinating their migration or first employers at destination (sometimes the debt was transferred from the intermediaries to the employer). This rule assumes that *Migrants* are always partial to being indebted to family before 'industry' (i.e., intermediaries and employers), because family members less frequently charge interest and industry almost always does. But if the migrant's nuclear family does not have enough excess wealth (above 0.2 in this rule) to pay for the migration costs then a migrant is forced to take on debt to 'industry'. For simplicity and due to limited data, this rule does not consider that migrants might handle finance differently based on factors other than family absolute wealth.

20a. Migration costs rule

*costTransit = durationTransit(t) * costDailyTransit + costDocTransit*
costDocumentation = sum of costs in documentation(t) array + costFailedPassport
costFees = sum of fees of Intermediaries in migrationNetwork(t)

IF *Migrant has arrived at planned destination*
THEN
    cost = costTransit + costDocumentation + costFees
    wealth(t) = wealth(t-1) - cost
    Acquired migration debt rule (Rule 20b)
END

20b. Acquired migration debt rule

IF *wealth*(t) *< 0*
THEN
    IF *nuclearFamilyWealth(time step of leave decision) > .2*
    THEN
        debtFamily(t) = |wealth(t)|
        debtIndustry(t) = 0
    ELSE
        debtFamily(t) = 0
        debtIndustry(t) = |wealth(t)|
    END
ELSE
    debtFamily(t) = 0
    debtIndustry(t) = 0
END
End time-step
Wealth constraint (Rule 2d)

20c. Recurring border pass cost

IF *state = transit OR employed*
THEN
    IF *border pass is not expired*
    THEN
        Every 7 time-steps repeat:
            wealth(t) = wealth(t-1) – borderPass cost
            Wealth constraint (Rule 2d)
    END
END

21. Livelihood pressure and precarity rules

21a. Livelihood pressure rule. This is a multi-dimensional indicator of financial pressure using current debt, family wealth, and wages.

21b. Precarity rule. This is a multidimensional indicator of precarity using **livelihood pressure**, current documentation and location, and destination knowledge and support.

*Note: Only one indicator from each of the 1-8 groupings can count toward a single score. The total possible scores can range from 0-1. (e.g., a migrant that meets the criteria for 1 . . .8 gets the highest possible score of 1, a Migrant could meet none of the indicator criteria and thus have the lowest possible score of 0).

Rationale: Individual precarity (or 'hyper'-precarity) is a multi-dimensional outcome formalized in the model. The domain justification for the choice of this outcome and included indicators is in Section A.7.13.

21a. Livelihood score rule

livelihoodPressure(t) = sum of livelihood pressure indicators that apply

21b. Precarity score rule

precarity(t) = sum of all indicators that are TRUE

Livelihood Pressure	1. debtFamily(t) > wealth(t)	0.1
	2. debtIndustry(t) > 0	0.2
	3. familyWealth is in lowest 25% of households	0.1
	4. monthlyWages < .09 (i.e., below minimum wage)	0.1
Legal status	5a. no documents and in Mae Sot or Tak	0.1
	5b. no work permit and in Bangkok or Phang Nga	0.2
Knowledge & support at destination	6. this is the migrant's first migration	0.1
	7. no family at destination	0.1
	8. no viable, attractive alternative jobs (i.e., vacancy and higher wages and required documents satisfied)	0.1

22. Find employer or go to employer rules If a *Transit-Migrant* is at their planned **destination** but does not have an **employer plan** or was 'rejected' by their original **employer plan,** then their goal is to find an **employer**. First, they random walk within their destination and look for an *Employer* and request an offer from any *Employer* they find. See the Employer offer rule in Rule 34. **Rationale:** The MMSNA indicated that migrants who arrived at destination without a work plan or known employer would ask around at possible employers to see if there are any vacancies. In some cases, migrants explained that employers might require the migrant have a passport or workPermit (for that employer specifically – i.e., came through MOU channel) to work there). In those cases, the migrant was never offered employment. After extended periods of unemployment at destination a migrant is forced to return home due to the high cost of surviving at destination.	**22. Find employer or go to employer rule** IF *planEmployer(t)* = empty THEN IF *duration at destination* ≤ 100 THEN **Random walk rule** (Rule 1) *within destination sub-area* IF *any Employer is within Migrant's vision* THEN *request employment offer* ELSE *no change* END ELSE *walk home and pause all other function while walking home* *when at home state(t) = pre-migration* *motivation(t) = motivation(t-1) – 0.1* *deactivate most recent migration in the migrations array* **Motivation constraint** (Rule 3c) END ELSE IF *at planEmployer(t)* AND *currentEmployer(t)* = empty THEN *request employment offer* END END **End time-step**
23. Accept employment rule If a *Transit-Migrant* receives an **employment offer** they accept the offer and update their **state** to 'employed', add the *Employer* to their **migration network** and assign the *Employer* as their **current employer.** **Rationale:** This model assumes that, in this corridor and for this population of migrants, any migrant at destination without a source of income will accept any offer they receive.	**23. Accept employment rule** IF *Employer offer received* THEN *accept offer* *state(t) = employed* *currentEmployer = Employer's id* *migrationNetworkSize(t) = migrationNetworkSize(t-1) + 1* *migrationNetworkSize(t, migrationNetworkSize (t)) = Employer's id* END **End time-step**

Sub-Model 4 – Employment

Narrative Overview

The primary agent that executes the process in Sub-Model 4 (see Figure 62 and Table 56) is an *Employed-Migrant*. *Employed-Migrants* are no longer executing decisions and steps to migrate or to find work as they have now achieved these goals. An *Employed-Migrant* completes 6-month **work** cycles, during which they experience a **pay day** every month. On non-paydays, a *Migrant* might invite other family members to migrate, acquire new **documentation** through a *Thai-Doc-Broker*, or decide to return **home** 'early'**.** At the end of each **work** cycle, a *Migrant* is forced to assess their situation to decide if they will return **home** or continue working.

Figure 62 depicts the Sub-Model 2 process annotated with the rule numbers that correspond to Table 56. Figure 62 depicts the Sub-Model 4 process annotated with the rule numbers. Table 56 presents the **Sub-Model 3** *Employed-Migrant* agent rules in the order they are executed. Again, like the previous sub-models, it is implicit in Table 56 that a *Migrant* agent's **state** is 'employed'

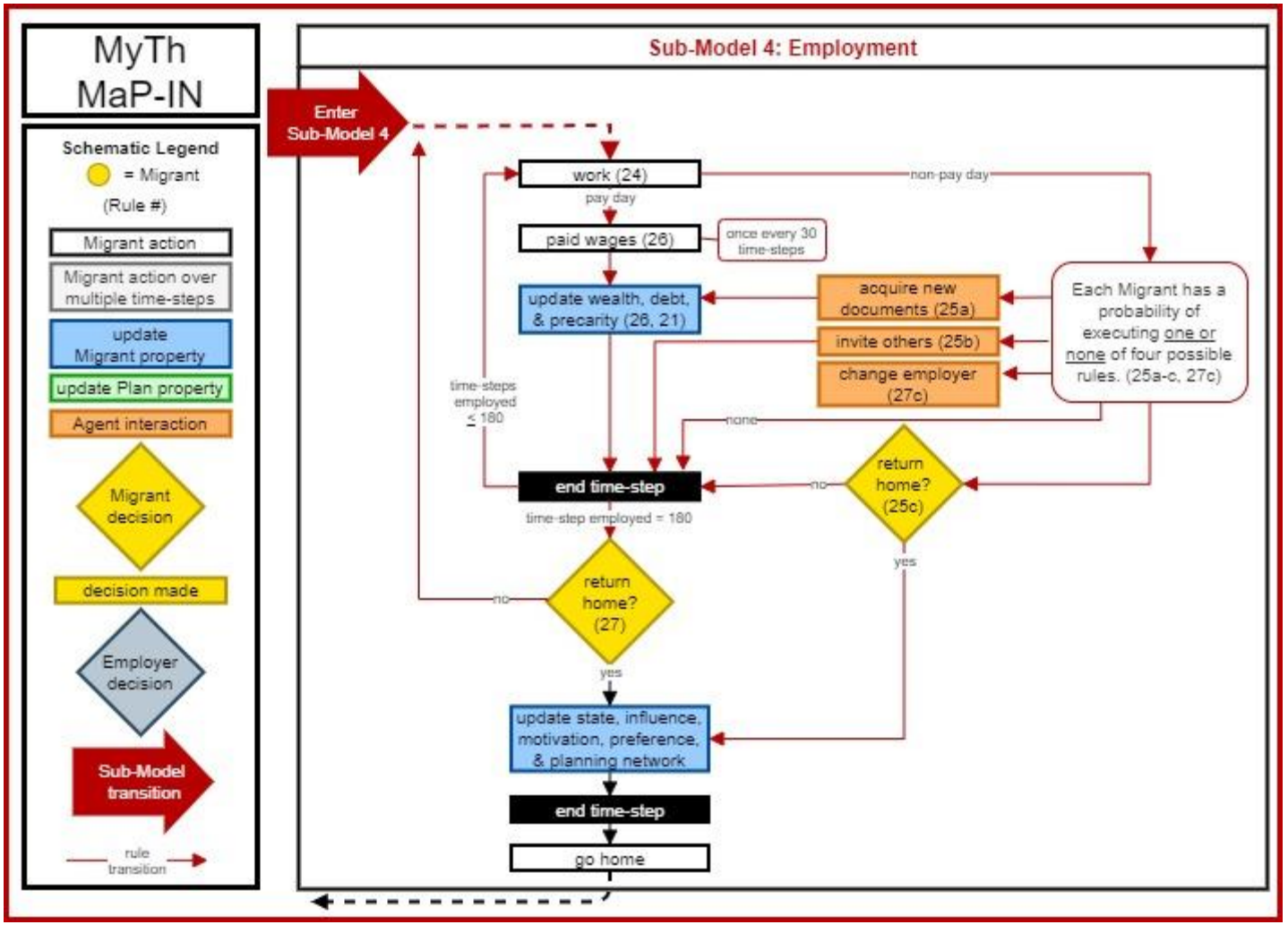


Figure 62. MyTh MaP-IN Sub-Model 4 schematic

Table 56. Sub-Model 4 rules

Rule description, rationale and calibration informed by McAlpine et. al.'s Myanmar-Thailand MMSNA study (215), University of Sussex's CHIME study (81), and the Myanmar Living Conditions survey (260).	**Model based rule** (IF-THEN or basic equation)
<u>24. Work rules</u> **24a. Work rule** An *Employed-Migrant* works for 180 time-steps (i.e., 6 months). Once a month they experience a **pay day** like the pattern of the **wealth fluctuation** in Sub-Model 1. Otherwise, they may complete other actions while at destination (Rule 26) during their non pay days. N.B. The % symbol in this rule is not being used to represent a percentage, but instead it is a common programming notation for the modulo operator (i.e., returns the remainder left over when one operand is divided by a second operand). **24b. Solicited offer response rule.** If an *Employed-Migrant* receives a request for an offer from a *Planning-Migrant* (Rule 9) then they respond with an offer 70% of the time. **Rationale:** In an aim of keeping the model simple but true to the research question, migrants work for set cycles of 6-months, with opportunity to execute one of a few typical 'changes' at destination. Migrants can, although rarely, choose to go home before the end of 6-motnths of working. This was reflected in the MMSNA where most migrants stayed in first employment for at least 3-6 months to earn livelihood or pay off migration expenses before attempting to change employers, migrate onward, or return home. Most migrants stay on average between 2-3 years in Thailand so for this model we assumed 6-months without a required decision point was an accurate reflection of destination dynamics (81, 82). Additionally, migrants can invite family from Myanmar, a typical trend in many low-wage labour migration corridors and evident in the MMSNA given most migrants were invited by social contacts at destination. Finally, migrants that are undocumented can also attempt to secure documentation at destination to decrease precarity or increase earning power, both of which were described as motivation for pursuing new documents in the MMSNA. Migrants also mentioned fearing deportation and wanting to secure documents through their employer or local Thai brokers (215).	**24a. Work rule** IF *durationEmployed(t) ≠ 180 (or multiple of 180)* THEN IF *(current timestep – monthlyWealthFluctuationOffset)%30 != 0* THEN IF *preference = legal* THEN **Request Thai-Doc-Broker offer rule** (Rule 25a) *with (probability = 0.08)* **Invite family rule** (Rule 25b) *with (probability = 0.01)* **Return home early rule** (Rule 25c) *with (probability = 0.01)* *Skip all rules with (probability = 0.90)* ELSE IF *preference = social* OR *family* **Request Thai-Doc-Broker offer** (Rule 25a below) *with (probability = 0.01)* **Invite family rule** (Rule 25b below) *with (probability = 0.08)* **Return home early rule** (Rule 25c below) *with (probability = 0.01)* *Skip all rules with (probability = 0.90)* ELSE **Request Thai-Doc-Broker offer** (Rule 25a) *with (probability = 0.01)* **Invite family rule** (Rule 25b) *with (probability = 0.02)* **Return home early rule** (Rule 25c) *with (probability = 0.01)* **Change employer** (Rule 27c) with *(probability = 0.01)* *Skip all rules with probability = 0.95* END ELSE **Payday rules** (Rule 26) END ELSE **Return home decision** (Rule 27) END **24b. Solicited offer response rule:** IF *received request from Planning-Migrant*

	THEN *make offer with (probability = 0.7)* *do not make offer with (probability = 0.3)* END

25. Non pay day actions rule

On a non-payday time-step, an *Employed-Migrant* might execute one of three possible actions below based on the probabilities and conditions in Rule 24.

25a. Request Thai-Doc-Broker offer rule. If an *Employed-Migrant* does not have a valid work permit, then they might request help from a *Thai-Doc-Broker* to acquire new **documentation**. See the *Thai-Doc-Broker actions* in Rule 35b.

25b. Invite family rule. If an *Employed-Migrant* has low or medium precarity then they invite their extended family member with the highest **motivation** to migrate. See *Pre-migration-Migrant* response is in Rule 5+6.

25c. Return home rule. If an *Employed-Migrant* does not have a valid work permit or has not satisfied their migration preferences, they have a higher probability of deciding to return **home** before the end of the 6-month work cycle.

An Employed-Migrant will only do one or none of these actions (25 b-d) on a non-payday and none of them on a payday.

Rationale 25a: A migrant without a work permit that is presented an opportunity to secure documentation will likely accept and for this model, given the low probability of this rule executing, migrants will always accept this potential offer for documents. However, the MMSNA qualitative narratives about the exchanged between migrants at destination and Thai-based document brokers indicated that these can be high risk transactions because migrants pay the full cost up front with no guarantee of service and it is increasingly difficult to secure work permits outside of the Myanmar-side initiated MOU process (215). Therefore, distinct from the Myanmar-Document-Broker transactions, Thai-Doc-Brokers do not always deliver on the services (they do according to their 'completion rate') but do always charge the costs up front.

Rationale 25b: Myanmar-Thailand migration is often facilitated by social contacts, usually family at destination (81). This rule, like the unsolicited family offers rules in Sub-Model 2, reflects the trend in Myanmar migrants in Thailand to create opportunities for their kin abroad. In most of the

25a. Request Thai-Doc-Broker offer rule

IF *documentation(t) does not include a work permit*
THEN
    possibleThaiDocBrokers = Thai-Doc-Brokers in planningNetwork(t) OR *currentEmployer's links*
    randomly select one Thai-Doc-Broker from possibleThaiDocBrokers

    migrationNetworkSize(t) = migrationNetworkSize(t-1) + 1
    migrationNetworkSize(t, migrationNetworkSize (t)) = Thai-Doc-Broker's id
    wealth(t) = wealth(t-1) – Thai-Doc-Broker's fees - docCosts

    receive work permit with (probability = Thai-Doc-Broker's completionRate)
    documentationSize(t) = documentationSize(t-1) +1
    documentationSize (t, documentationSize(t)) = work permit

    fail to receive work permit with (probability = 1- Thai-Doc-Broker's completionRate)

    Debt rule (Rule 26c)
    Wealth constraint rule (Rule 2d)
    Update precarity rule (Rule 21)
ELSE
    no change to migrationNetwork(t), documentation(t), debt(t), or precarity(t)
END
End time-step

25b. Invite family rule

IF *precarity(t) < .8*
THEN
    IF *currentEmployer's currentEmployees < maximumEmployees*
    THEN
        make offer to extended family Pre-migration-Migrant with highest motivation(t)
        offerDestination = destination
        offerEmployer = currentEmployer
    ELSE
        make offer to extended family Pre-migration-Migrant with highest motivation(t) with probability = 0.5
        offerDestination = destination
        offerEmployer = empty

        make no offer with probability = 0.5
    END

interviews, family proactively making invitations was an indication of their own security at destination and these invitations sometimes included employment offers through the destination-based family's current employment (215). **Rationale 25c:** while most migrants will aim to stay at destination to pay off costs and achieve livelihood goals, in some cases migrants may have reason to return home early. Two examples discussed in the qualitative date are migrants being forced to return home because they are deported (i.e., found out for not having valid work documents matching their current employer) or choosing to go home because they are not satisfied with their outcome. In the model, we have used unsatisfied preferences related to workplace as a proxy for motivation to return home early. Other indicators of workplace satisfaction related to profit from earnings are considered in the 6-month return home decision, not in the early decision here.	ELSE *do not invite family* END **End time-step** **25c. Return home rule** IF *documentation does not include a work permit* THEN *return home with (probability = 0.2)* *keep working with (probability = 0.8)* ELSE IF (*preference = sector* OR *wages* OR *proximity*) AND *preference is not satisfied* THEN *return home with (probability = 0.2)* *keep working with (probability = 0.8)* ELSE *no change* END **End time-step**

26. Pay day rules

Two global parameters are used in these rules:

debtPayRate *= 0.5*

interestRate *= 1.07*

26a. Wages and overtime rule. The wages a *Migrant* is owed **(wagesOwed)** are a combination of their monthly wage and any overtime they are paid.

26b. Deductions and paid wages rule. If a *Migrant* is in debt to the industry **(debtIndustry)**, they are forced to forfeit 50% of their wages to pay off debt (**debtPayRate**). Debt is increased by 7% fixed interest every payday. All *Employed-Migrants*, regardless of debt, may also experience other unlawful deductions from their wages (**monthlyDeductionRate**). These two forms of deductions together (**deductionRate**) are applied to a Migrants owed wages to determine their paid wages (**wagesReceived**). Final received wages get added to current wealth.

26c. Debt rule. Like the costs of migration (Sub-Model 3), any negative wealth is transferred to debt, in this case **debt to industry**. If a *Migrant's* **debtIndustry** increases they also then update their livelihood pressure and precarity. At the end of this rule wealth is constrained between 0-1.

26d. Industry debt payment. The paid debt is removed from the *Migrant's* current **debtIndustry.**

26e. Industry debt constraint. The paid debt is removed from the *Migrant's* current **debtIndustry.**

Rationale: The payday rule considers the many debits and credits that determine migrants' final profit from work, including, wages, deductions, paying off debt, and increasing debts. Migrants often experience 'wage theft' in multiple forms that can amount to exploitative employment practices and even debt bondage in the more sever cases (46). In the MMSNA, 27% of respondents missed some form of overtime pay, 56% of respondents were paid below minimum wage, and 58% experienced unlawful deductions from wages (215). Often these multiple forms of wage theft compound and create significant losses to migrants expected earnings. The MMSNA informed the types and frequencies of these different forms of wage losses.

26a. Wages and overtime rule

IF *timestep is payday*
THEN
overtimeOwed(t) = overtimeHours overtimeHourlyWage*
wagesOwed(t) = monthlyWage(t) + overtimeOwed(t)
Deduction and paid wages rule (Rule 26b)
END

26b. Deductions and paid wages rule

IF *debtIndustry(t-1) > 0*
THEN
*debtIndustry(t) = debtIndustry(t-1)*interestRate – wagesOwed(t)*debtPayRate*
deductionRate(t) = monthlyDeductionRate(t) + debtPayRate
Update livelihood pressure and precarity rule (Rule 24)
ELSE
deductionRate(t) = monthlyDeductionRate(t)
END

*wagesReceived(t) = (wagesOwed(t)*deductionRate(t))/2*
wealth(t) = wealth(t-1) + wagesReceived(t)

26c. Debt rule

IF *wealth(t) < 0*
THEN
add value below 0 to debtIndustry(t)
Update livelihood pressure and precarity rules (Rule 24)
ELSE
no change to debtIndustry(t), livelihoodPressure(t), or precarity(t)
END

Wealth constraint rule (Rule 2d)

26d. Industry debt payment and interest rule

*debtIndustry(t) = debtIndustry(t-1) – wagesOwed (t)*debtRate*

26e. Industry debt constraint: *debtIndustry(t)* = MIN[1,MAX[0,debtIndustry(t)]

27. Return home decision

A global parameter used in this rule is:
savingsGoal = 3*monthlyWages

27a. Leave job decision. After a 6-month work cycle, an *Employed-Migrant* must decide whether to keep working at their current employer, go to a new employer, or return home. They make this decision based on their current debt, wealth, and, in some cases, whether their current migration is meeting their preference.

27b. Return home decision.

27c. Find new Employer
If a *Migrant* decides to go to a new *Employer.* They identify any *Employer* that either:

- Pays higher **wages** than their **current employer**; or
- Satisfies their **sector** or **wages preferences**

If they identify an *Employer*, the *Employer* must meet these 3 criteria for the *Migrant* to change *Employers*:

- Be in the *Migrant's* **destination** sub-area
- Be satisfied with the *Migrant's* documentation (i.e., *Migrant's* **documentation** satisfies *Employer's* **requiredDocuments**) docs match required docs
- Have vacancy (i.e., **currentEmployees**(t) < **maximumEmployees**)

If the *Migrant* had a work permit at their previous *Employer* but is changing *Employer,* then they now loose their work permit. If the Migrant does not identify an Employer or the Employer does not meet the criteria, then the Migrant instead returns home.

Rationale: After 6-moonths, all migrant agents in the model assess their situation. Migrants consider their debt to industry, workplace preferences, wealth improvements (or losses), and outstanding debt to family they will need to pay back on return. Most migrants have the base aim of paying the costs of their migration and returning home with some profit which we have assumed to be at least 3-months Thai minimum wage (0.027). Migrants that are in debt to industry cannot leave their current employer as it is assumed the debt it to that employer or associates and is tying the migrant to that workplace.

27a. Leave job decision

IF *durationEmployed(t) = 180 (or multiple of 180)*

THEN
IF *debtIndustry(t) > 0*
THEN
stay at current employer
ELSE
IF *preference = sector OR wages AND is not satisfied*
THEN
IF *wealth(t) > (savingsGoal + debtFamily)*
THEN
stay at current employer with (probability = 0.1)
Find new employer (Rule 27c) *that meets preference condition with (probability = 0.1)*
Return home decision (Rule 27b) *with (probability = 0.8)*
ELSE
stay at current employer with (probability = 0.1)
Find new employer (Rule 27c) *that meets preference condition with (probability = 0.6)*
Return home decision (Rule 27b) *with (probability = 0.3)*
END
ELSE
IF *wealth(t) > (savingsGoal + debtFamily)*
THEN
stay at current employer with (probability = 0.5)
Return home decision (Rule 27b) *with (probability = 0.5)*
ELSE
stay at current employer with (probability = 0.3)
Find new employer (Rule 27c) *that pays higher wages with (probability = 0.6)*
Return home decision (Rule 27b) *with (probability = 0.1)*
END
END
END
END

27b. Return home decision.
IF *decided to return home*

Migrants that have not made the minimum 3-month profit are more likely to decide to find a new employer that pays higher wages, and for this with an unsatisfied workplace preference they will look for an employer that satisfies that preference. In the MMSNA study, 51% of respondents had more than one employer actor in their migration network indicating a frequency with which Myanmar migrant change employers in Thailand despite the regularised formal channels including increased barriers to trying to change employers. Many migrants described learning about better or higher paying employers or more 'comfortable' jobs with better hours after arriving and becoming more familiar with the destination (215).	*THEN* *walk home and pause all other function while walking home* *when at home state(t) = pre-migration* *deactivate most recent migration in the migrations array* *pay off debtFamily from wealth* *disperse remaining wealth equally across nuclear family, including themselves* IF *wealth(t) > (savingsGoal + debtFamily)* THEN *influence(t) = influence * 1.25* **Influence constraint** (Rule 6b) ELSE *planningNetwork(t)* = empty END END **27c. Find new Employer** IF *decides to find new employer* THEN IF *any employer in destination meets the Migrant's selection criteria* (i.e., higher wages OR satisfies preference) THEN IF *Migrant's documentation(t) satisfies Employer's requiredDocumentation* THEN IF *Employer's currentEmployees(t) < maximumEmployees* THEN *currentEmployer(t) = new employer's id* ELSE *walk home and pause all other function while walking home* *when at home state(t) = pre-migration* *deactivate most recent migration in the migrations array* IF *wealth(t) > (savingsGoal + debtFamily)* THEN *influence(t) = influence * 1.25* **Influence constraint** (Rule 6b) ELSE *planningNetwork(t)* = empty END

	END END END END IF *migrant changes employer* THEN IF *documentation(t) includes 'work permit'* THEN *remove work permit* END END

Sub-Models 1-4 – Intermediary and Employer rules

Figure 63 and Table 57 describe the *Intermediary* and *Employer* agent processes and rules that are executed across Sub-Models 1-4. These rules were referenced in the other sub-model figures and tables.

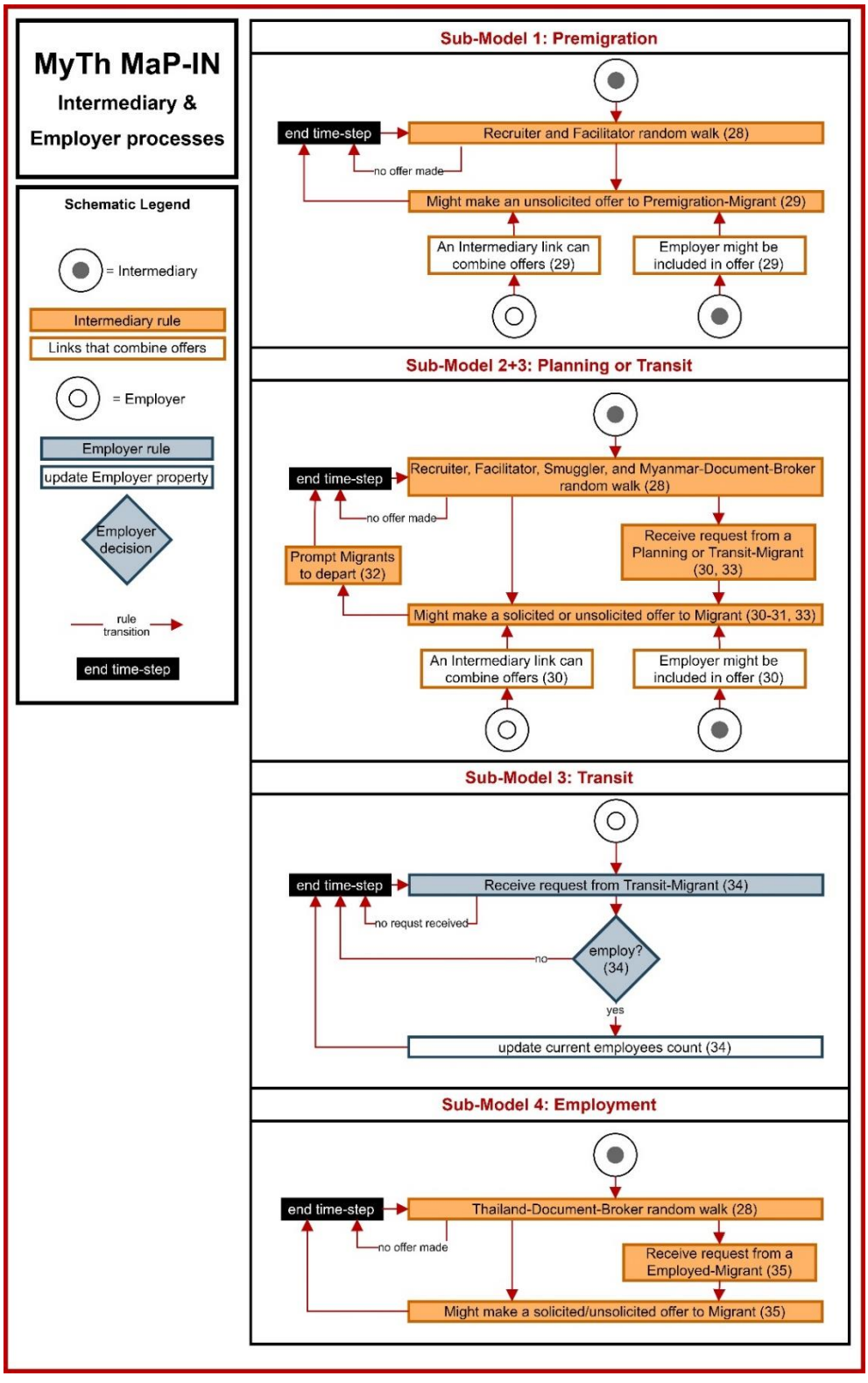
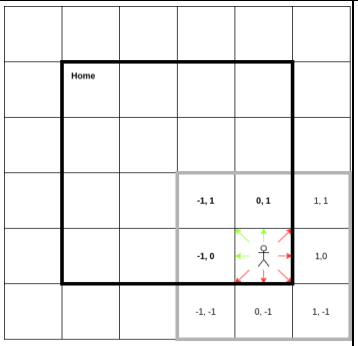


Figure 63. MyTh MaP-IN Sub-Models 1-4 Intermediary and Employer schematic

Table 57. Sub-Model 1-4 Intermediary and Employer rules

Rule description, rationale and calibration informed by McAlpine et. al.'s Myanmar-Thailand MMSNA study (215), University of Sussex's CHIME study (81), and the Myanmar Living Conditions survey (260).	**Model based rule** (IF-THEN or basic equation)
28. Intermediary movement rules Same as *Migrant* **Random walk rule** (Rule 1). Note: Smugglers only are also constrained to a smaller area within Myawaddy near their border crossing to allow Migrants looking for a Smuggler to do so within a smaller geographic area.  **Rationale:** This rule allows for similar chance encounters as between migrant agents. Non-spatially conditioned interactions take place through agent links and networks (described in other rules). In the MMSNA qualitative narratives, migrants described meeting intermediaries in their communities, in transit, or nearby points of interest. Intermediaries' location assignments are informed by the typical locations and processes associated with specific intermediary types.	**28a. Intermediary random walk rule** Same as 1a, but for agent = intermediary. **28b. Intermediary random walk constraint** Same as 1b, but for agent = intermediary.
29. Recruiter and Facilitator unsolicited offer rule Some *Pre-migration-Migrants* receive an **offer** to migrate from an *Intermediary* agent. If a *Pre-migration-Migrant* is within a *Recruiter* or *Facilitator's* **vision**, then the *Intermediary* makes an unsolicited **offer** to the *Pre-migration-Migrant* 70% of the time. See *Pre-migration-Migrant* response is in Rules 5 and 6. N.B. A *Facilitator* makes at least one offer with their own offer properties and possibly additional combined offers using the offer properties of agents in their **links**. The *Recruiter,* who may have multiple combinations of offer properties, always tries to make an offer that matches the Migrant's preference if possible and otherwise	**29. Recruiter and Facilitator unsolicited offer rule** IF *agent = Recruiter* or *Facilitator* THEN IF *Pre-migration-Migrant is within vision* THEN *make offers to Pre-migration-Migrant with (probability = 0.7)* *do not make offers with (probability = 0.3)* END END

selects randomly from possible offer properties. For example, if the *Migrant's* preference is to go where family is then if the *Recruiter* has a link to an *Employer* in the same destination as the *Migrant's* family, then the *Recruiter* makes this offer (whether directly or through the *Facilitator*). If not, then the *Recruiter* makes one offer with a randomly selected *Employer* and matching destination. **Rationale:** The MMSNA indicated that some intermediaries proactively recruit individuals to migrate and offer to arrange their migration and in some cases employment. The typical 'proactive' intermediaries that might make unsolicited offers the early stage of the migration planning, according to the MMSNA, are facilitators and recruiters which are more often involved in high-level migration planning not just specific migration steps (e.g., documentation or transport) that are more typically solicited offers (215).	
30. Solicited offer response rules See request offer rule in Rule 9. **30a. Solicited intermediary offer response rule** If an *Intermediary* receives a request from a *Planning-Migrant,* they respond with an **offer** 90% of the time. **30a. Solicited intermediary offer response rule** If an *Employed-Migrant* receives a request from a *Planning-Migrant,* they respond with an **offer** 70% of the time. All other *Migrant* types (i.e., *pre-migration, planning, transit, returned*) do not make *offers*. N.B. An agent makes at least one offer (i.e., one set of offer properties) and possibly additional combined offers using the offer properties of agents in their **links,** in the case of intermediaries, or migration network, in the case of migrant agents. **Rationale:** Intermediaries are proactively looking for and responding to clients. This model assumes that any active intermediary is unlikely to turn down the opportunity for a customer. Meanwhile, migrants at destination often take on risk, costs, or burdens to help another family member migrate and often without direct financial gain or incentive (215).	**30a. Solicited intermediary offer response rule** IF *agent = Recruiter* or *Facilitator* THEN IF *request received from Planning-Migrant* THEN *make offers to Pre-migration-Migrant with (probability = 0.9)* *do not make offers with (probability = 0.1)* END END **30b. Solicited migrant offer response rule** IF *agent = Migrant* AND *state = employed* THEN END
31. Myanmar-Document Brokers unsolicited offer rule *Myanmar-Document-Brokers* stay in the vicinity surrounding the passport offices looking for *Migrant* agents to **offer** passport help to.	**31. Myanmar-Document Brokers unsolicited offer rule** IF *agent = Myanmar-Doc-Broker* THEN IF *Planning-Migrant is within vision*

They always make an offer to any *Migrant* that comes within their **vision.** **Rationale:** The egocentric network data indicated that some 'brokers' work specifically in the documentation process, on both the Myanmar and Thai side of the corridor (215). Because work permits are arranged by recruitment agencies, the Myanmar side document brokers most often coordinated the passport process for individuals that were unable to navigate the process by themselves. These actors took fees up front for their help and often guaranteed successful application. The qualitative narratives described these actors as being recognizable and available around the passport offices (215).	THEN *make offerDocumentation = passport to Planning-Migrant* END END
<u>32. Departure rules</u> **32a. Recruiter departure rule** *Recruiters* do not send *Migrants* to Myawaddy until they have a 'large enough' group to send to a singular employer. **32b. Smuggler departure rule** *Smugglers* do not take *Migrants* to their destination (or employer) until they have a 'large enough' group of passengers for the transit. **Rationale:** Both recruiter and smuggler agents work on 'economies of scale', which means they look to coordinate for a group of migrants to maximise profits but also minimise administrative work (91, 215). In the case of recruiters, they are also often meeting the demand of an employer. To simplify the attributes, we have assigned to employers, the model assumes that recruitment agencies are often recruiting similar 'bulk' numbers of workers for their employer clients.	**32a. Recruiter Yangon departure rule** IF *class = agency* THEN IF *agency's total recruited migrants with the same planEmployer(t) is ≥ agency's recruitMinimum* THEN *send those recruits to Myawaddy* ELSE *Migrants stay at agency* END END **32b. Smuggler departure rule** IF *agent = smuggler* THEN IF *smuggler's total passengers with the same planDestination(t) ≥ passengerMinimum* THEN *send all Migrants to destination with that planDestination(t) to destination* ELSE *Migrants stay in Myawaddy* END END
<u>33. Smuggler solicited offer rule</u> If a *Smuggler* receives a request for a **transport offer** and they coordinate transport to the **destination** the *Migrant* is planning to go to then they always make an offer.	**33. Smuggler solicited offer rule** IF *agent = smuggler* THEN IF *request received* THEN

Rationale: The MMSNA indicated that smugglers were readily available in Myawaddy to coordinate transport on specific routes to popular migrant destinations. Smugglers would make offers to any migrant customers wanting to travel on said routes regardless of other attributes about the migrant (215). Even the costs of this transaction could be covered up front or often transferred as debt to employers or family upon arrival(215).	IF *offerDestination = Migrant's planDestination(t)* THEN *make offerTransport = smuggler's id and offerBorderCrossing = 'unofficial2'* END END END
34. Employer response to request rule Once a *Transit-Migrant* has arrived at the *location* of their *employer-plan* they then need to decide whether to take the employment. This decision is first contingent on the *employer* still having a *vacancy* and on the *employer's document-requirements* matching the *documents* the *Migrant* has acquired.	**34. Employer response to request rule** IF *agent = employer* THEN IF *request received for Transit-Migrant* THEN IF *currentEmployees < maximumEmployees* THEN IF *Migrant's documentation(t) satisfies requiredDocumentation* THEN *Make offerEmployment = employer's id with (probability = 0.9)* *do not make employment offer with (probability = 0.1)* END END END END
35. Thai-Doc-Broker offers **35a. Unsolicited offer** *Thai-Doc-Brokers* make **offers** to help with **documents** to any *Migrant* (regardless of state) that comes into their **vision.** **35b. Solicited offer** *Thai-Doc-Brokers* make **offers** to help with **documents** to any *Migrant* (regardless of state) that requests an **offer.** **Rationale:** Like Myanmar based document brokers and other intermediaries, the Thai based document brokers are incentivised to make profit and therefore do not turn down possible customers. These brokers make offers through direct contact but also through requests from migrants that know about their services from previous interactions or from links to the migrant's employer (215).	**35a. Thai-Doc-Broker unsolicited offer** IF *agent = Thai-Doc-Broker* THEN IF *Employed or Transit Migrant is within vision* THEN *make offer* *Migrant's planningNetworkSize(t) = planningNetworkSize(t-1) + 1* *Migrant's planningNetwork(t, planningNetworkSize(t)) = id of Thai-Doc-Broker* END END **35b. Thai-Doc-Broker solicited offer** IF *agent = Thai-Doc-Broker* THEN IF *request received from Employed-Migrant*

	THEN *make offerDocumentation(t) to match request for passport AND/OR work permit* END END

A.7.18 Verification

"A prerequisite to understanding a simulation is to make sure that there is no significant disparity between what we think the computer code is doing and what is actually doing." (266, 1.3)

We have completed verification steps to check the 'internal validity' of the MyTh MaP-IN ABM. Our verification process set out to answer these questions:

1) Do the lines of code (i.e., the computational model) map to the conceptual model as describe in the Sub-Model schematics and IF-THEN rules?
2) Are there any semantic or logical errors in the code?
3) Are there any artefacts (i.e., unintended or unnamed assumptions) that might be significantly influencing the model observations?

Verifying any ABM is challenging because the aim of the method is to study emergence, so it can be difficult to distinguish 'unexpected' outcomes resulting from the complexity of the model as opposed to unexpected outcomes due to an error or artefact in the model code (266, 267). This is particularly difficult when a simulation includes many heterogenous interactions and decisions, such as in the MyTh MaP-IN ABM. This work was guided by multiple sources for technical guidance (152, 284, 309), most notably the work of Galan and colleagues describing errors and artefacts in ABMs (266).

Sub-Model Verification Stages

The MyTh MaP-IN sub-models were each checked for errors and verified progressively in four stages (i.e., Sub-Model 1, Sub-Models 1-2, Sub-Models 1-3, and Sub-Models 1-4) for artefacts. It was not within the scope of this work to verify Sub-Models 2, 3 and 4 outcomes isolated from the preceding Sub-Models, although this is an area of potential future verification methods. Likewise, it was not within the scope of this work to use any formal methods of verification, such as model replication or exploring multiple updating techniques (277). These formal methods of replication offer new ways to interrogate models for any underlying artefacts causing the model's

emergent properties, instead of the explicit mechanisms being modelled. Other similar work has been attempted to reproduce an original model using a different modelling method to both verify and validate the original model (277, 278). These formal methods are outside the scope of this work but are evaluation methods to consider applying in the future.

Sub-Model Verification Steps (at each 'stage')

The verification process for this ABM included the following three steps:

Step 1: Identify semantic errors - Are there any typos or naming mistakes?

Semantic errors: In a similar style to 'paired programming', the programmer and modeller have worked together to iteratively check the code for any typos or naming errors. The modeller used the Sub-Model documentation as a guide while reviewing the ABM code to ensure agents, variables, and rules had been named consistently and that the code was written in a similar narrative order as the Sub-Model schematics and tables to ensure easy cross-referencing between the documentation and the code.

Step 2: Identify logical errors - Does the computational model (i.e., lines of code) execute the essence of the outlined conceptual model (i.e., IF-THEN rules)?

Logical errors: Again, using the Sub-Model documentation as a guide, the modeller and programmer checked the code to identify any logical discrepancies between what the rules were instructing to happen and what the code was executing. Through this process, the modeller and programmer also added additional annotations to the code to explain the logic of the rules in a way that will help others with a range of technical backgrounds understand the code.

Step 3: Expected outcome alignment and artefact checking: Given the trends when rules are fired and the higher-level outcomes, are there any possible assumptions underlying the rules that are misaligned with the target phenomenon, as described in the conceptual model?

Expected outcome alignment and artefacts: The modeller and programmer independently review the data output files to review the range and distribution of parameter values for any obvious abnormalities. The data output is also checked for how often rules were 'fired' and to what affect. This step also includes a higher-level check of aggregate outcome trends (i.e., how many migrants change state, how many migrants use certain pathways) to see if the general dynamics of the sub-model align with expectations of that sub-model. Reviewing the frequency and trends of rule firing and outcomes will help to identify any artefacts (i.e., assumptions in the model that the modeller or programmer may have thought were insignificant or did not know were there but are having significant impact on model outcomes). A full list of model assumptions can be found in Section A.7.19.

The two error checking steps were repeated for each sub-model and the expected outcome alignment and artefact checking were completed for Sub-Model 1, Sub-Models 1-2, Sub-Models 1-3, and Sub-Models 1-4, detailed in Appendix 8.

A.7.19 Sensitivity analysis

The MyTh MaP-IN has many parameters, and it was outside of the scope of this thesis to evaluate the sensitivity of the model outputs to every model parameter. Instead, the sensitivity analysis (SA) focused on evaluating the sensitivity of the model outputs to two key model attributes that might have a strong influence on the migration process (planning and execution) and be most relevant to intervention responses – migrant **preferences** and intermediary **links.** To test the sensitivity of the model to the interaction of these two model features, we have established three possible values for each feature and combined them in nine different ways (Table 58).

Table 58. Sensitivity analysis two-factor combinations

Sensitivity Analysis - Model elements		
	Migrant preferences	**Intermediary to Intermediary links**
Baseline	intermediary = 15% family =15% legal = 5% fees = 5% social = 15% work = 15% sector = 15% wage = 10% proximity = 5%	Facilitator-Recruiter = 25% MDB-Recruiter = 10% Employer-TDB = 50% Facilitator-Smuggler = 100% Facilitator-Employer = 25% Recruiter-Employer = 100% Smuggler-Employer = 10%
Value 1	**Migration Focus:** intermediary = 25% family =25% legal = 25% fees = 25% ELSE = 0%	**Fewer Links:** Facilitator-Recruiter = 0% MDB-Recruiter = 0% Employer-TDB = 25% Facilitator-Smuggler = 50% Facilitator-Employer = 25% Recruiter-Employer = 75% Smuggler-Employer = 0%
Value 2	**Destination Focus:** social = 20% work = 20% sector = 20% wage = 20% proximity = 20% ELSE = 0%	**More Links:** Facilitator-Recruiter = 50% MDB-Recruiter = 35% Employer-TDB = 75% Facilitator-Smuggler = 100% Facilitator-Employer = 75% Recruiter-Employer = 100% Smuggler-Employer = 35%

Model element - Combinations		
id	**Migrant preferences**	**Intermediary to Intermediary links**
SA1	**Baseline**	**Baseline**
SA2	**Baseline**	**Value 1**
SA3	**Baseline**	**Value 2**
SA4	**Value 1**	**Baseline**
SA5	**Value 1**	**Value 1**
SA6	**Value 1**	**Value 2**
SA7	**Value 2**	**Baseline**
SA8	**Value 2**	**Value 1**
SA9	**Value 2**	**Value 2**

A.7.20 Validation

The MyTh MaP-IN model was validated at multiple levels (Table 59).

Table 59. Multi-level validation

Level of representation		Validated elements	Validation method
Micro-level	**Entities, properties, & rules**	• Preference • Initiation • Offers • Decisions • Plans	Inductive analysis that purposively compared the interview data from a set of randomly partitioned interviews (not included in the primary MMSNA study) to the ABM's micro-level model elements listed in this table.
	Processes	• Network emergence • Pathways	
System-level	**Patterns**	• Percentage of population that migrate • Percentage of regular vs. irregular pathways • Range of precarity scores across all migrants	Comparison of simulation event or outcome trends with similar quantitative empirical findings.

Micro-validation. For this first iteration, our model validation prioritised first validating the model rules. To do this, we partitioned a random 15% of the interviews for each of the three data collection site (n=15 interviews partitioned in total) and did not use these interviews in the primary MMSNA analysis presented in McAlpine and colleagues' corresponding paper which informed the model rules (215). After completing the model design and build, A. McAlpine compared the rules of the model and observed agent pathways to the migration narratives in these interviews to check if the model comprehensively included all these partitioned interview narratives, checking both that nothing of critical importance was missing from the model but also that nothing in the model contradicted the narratives in these interviews.

Additionally, the partitioned interview network data (i.e., structured egocentric network formations) were compared to the simulated emergent

networks outputs in the model, again to check that the network structures presented in the interviews were represented in the simulated data as well.

System-validation. Also, as part of a first stage of validation of the model, we used the empirical data that informed the ABM, as well as the CHIME study and MLS survey to qualitatively validate the model outputs. We compared the total number of migrants that decided to migrate per simulated household to the population level findings of the CHIME and MLS survey. We assumed some of those figures were underestimates due to measurement challenges and missed households that migrated together and were not included in the surveys. We used the empirical data collected for this study to compare the baseline simulation's distribution of migrations across the different pathways and estimates for similar precarity indicators to check that the migration pathways and precarity outputs reflected the outcomes in our empirical data.

Due to Covid-19 restrictions, full validation of the model with expert stakeholder groups has not yet been feasible or within the scope of this work. In the future, we intend to complete additional model rule and initial full model validation with expert stakeholder groups, including groups of migrant workers.

Part 4: Next steps

A.7.21 Future validation

This ABM will undergo the following future validation steps that were outside of the scope of this initial work and/or infeasible due to Covid-19 restrictions:

- Validation workshops with groups of migrant workers with a focus on the preference and decision-making processes.
- User validation and testing workshops (conducted for various use cases, such as using the ABM to develop future research agendas, design and test programmatic interventions; design and test policy; inform funder priority areas).
- Develop possible ABM validation criteria to use for ABMs informed by qualitative or mixed-methods data sources that cannot be validated using large representable datasets due to availability or access.
- Test for model structural uncertainty.

A.7.22 Future MyTh MaP-IN iterations and analysis

This model will continue to be iterated and developed in future work. Some areas that have been identified for future iterations and analysis include:

- **Extending the heterogeneity of 'social influence':** add more diverse interactions between 'home' and 'destination (e.g., social media) and more exchanges that represent 'weak ties' (310).
- **Incorporate decision-making under uncertainty:** distinguish between 'known' and 'unknown' plans and incorporate these distinctions into how migrants make decisions.
- **Add more in-depth empirical perspectives from non-migrant agents:** conduct interviews with intermediaries and employers to better understand and formalise their behaviours and interactions in the system.

- **Employment heterogeneity:** add more heterogenous attributes for workplaces and employers such as working conditions and labour rights that can be used to look at other indicators of precarity such as occupational health or freedom of movement.
- **Allow for emergent links between intermediaries:** with more insights from intermediaries, the mode could include emergent links between intermediary actors as the result of spatial or social network interactions.
- **Seeding the model with 'history':** attempt to start the model with some 'history' (e.g., migrants employed at destination, migrations in process, migrant networks populated) that is appropriate for the Myanmar-Thailand context; could do this by letting the model is run for 100 time-steps to allow some 'seed' data to populate the model before beginning to output the model data for analysis
- **Different precarity comparisons:** the precarity outcome, which is currently compared across pathways, could also be compared across different sub-groups (e.g., migrants that started Sub-model 2 at 2A versus 2B, migrants from different origin areas, etc.)

A.8 Paper 4: MyTh MaP-IN ABM results – Supplementary materials

A.8.1 Model documentation

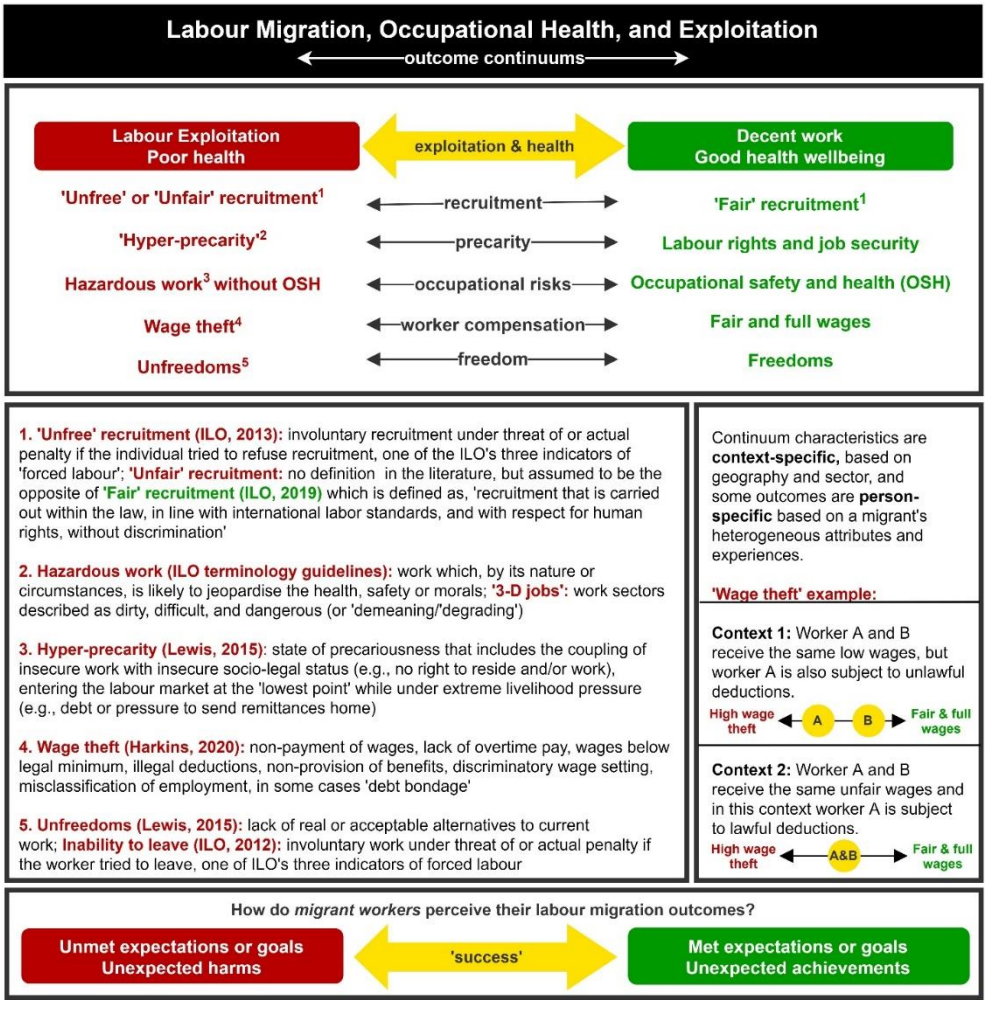
The MyTh MaP-IN model code, ODD+2D protocol, and supplementary documentation can be accessed via GitHub (305). The model can be viewed and interacted with via browser:

www.alysmcalpine.com/research/mythmapin/

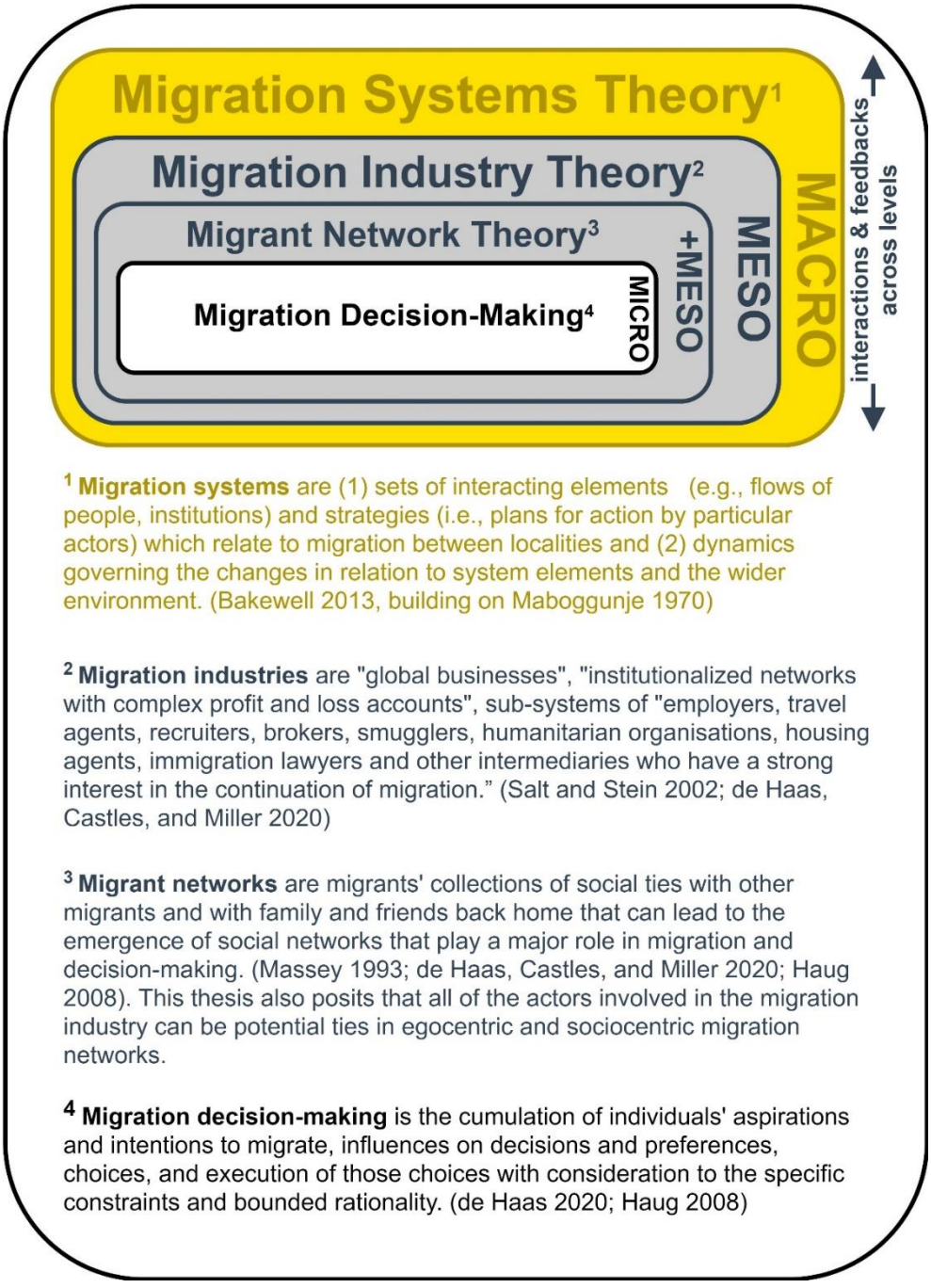
The model is in the process of being made public via the CoMSES OpenABM model library (262).

A.8.2 Study conceptual and theoretical frameworks

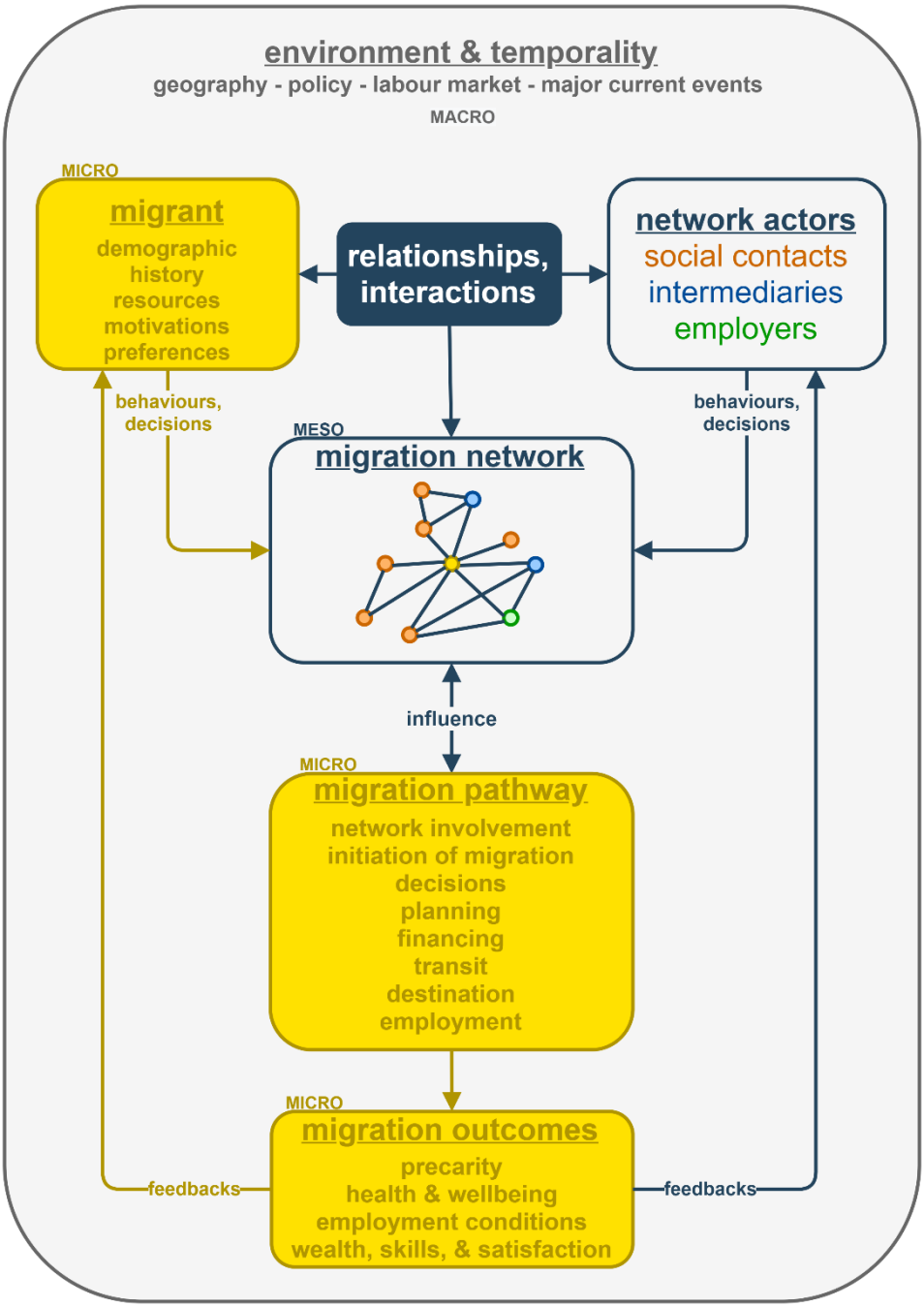
This section presents three frameworks that guided this research: 1) conceptual framework of labour migration outcome continuums; 2) theoretical framework of multi-level migration theories; and 3) conceptual framework of a complex low-wage labour migration system.



Repeated Figure 2. Labour migration outcome continuums



Repeat Figure 4. Multi-level migration system theoretical framework with definitions



Repeated Figure 6. Complex low-wage labour migration system conceptual framework

A.8.3 Simulation Verification

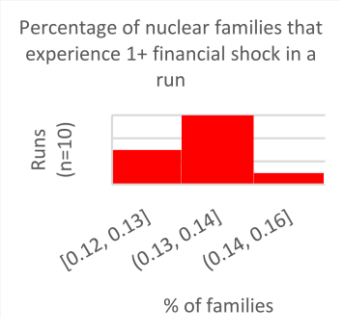
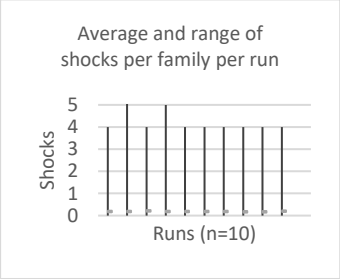
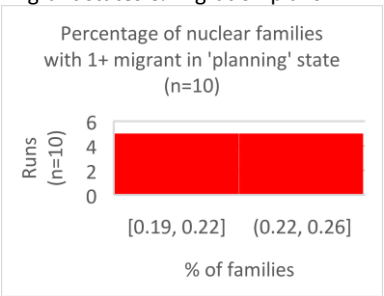
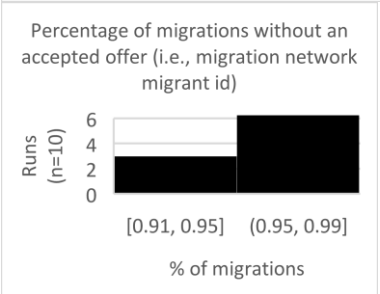
Table 60 details the simulation verifications steps and observations. Steps 1 & 2 were completed for each sub-model, guided by the ODD+2D protocol. Step 3 was executed four times, once after each sub-model was *added*. Due to size and scope of the model, Step 3 was limited to select model elements we identified as having more influence on model outcomes. The aim was to identify any obvious anomalies within what was feasible. Each Step 3 stage included 10 runs, at which point the statistics became relatively stable enough to verify trends. We repeated the four stages of Step 3 three times to continuously check the impact any changes or calibration were having on the model outputs. The table below only included the final outputs after we completed the verification of certain model elements (highlighted in **red**). Column 3c includes our notes of this process.

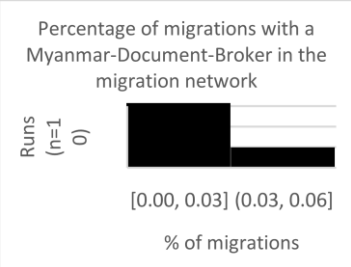
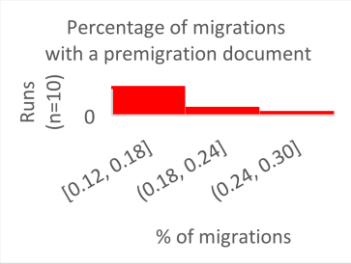
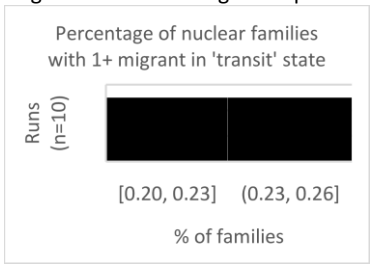
Table 60. Verification steps

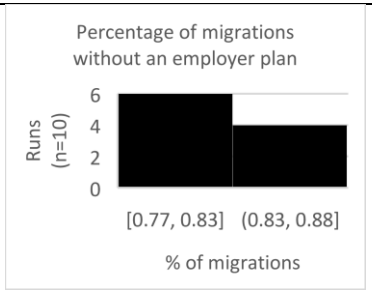
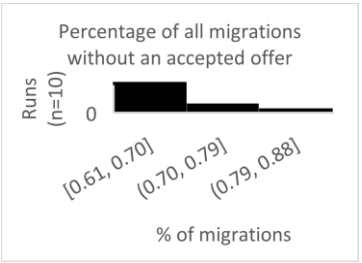
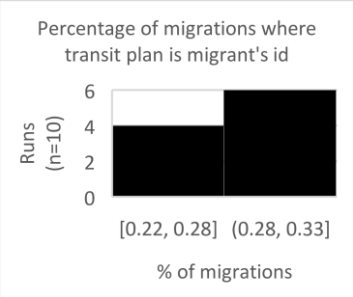
STEP 1. Semantic errors – a continuous process during model development, documentation, and final verification.		
Sub-Model	**1a. Syntax errors:** Checked code and annotations for any spelling, naming, or clarity issues.	**1b. Rule order:** Checked code included all rules in the right order.
1	• Renamed 'payDay' to 'wealthFluctuation': removed implication of increase only • Renamed 'regionalWealth' to 'subAreaWealth': makes terminology consistent • Fixed inconsistent naming of 'Document' vs. 'Passport' Brokers	• Added rule numbers to units of code to verify order • No order errors or missing rules
2	• Added distinctions in the annotations between *unsolicited* and *solicited* offers. • Added rule numbers to units of code.	• Added rule numbers to units of code to verify order • Added Rule 11: returned migrants shares agent IDs
3	• No errors identified.	• Added rule numbers to units of code to verify order • Added Rule 19a: wait for smuggler 'prompt'
4	• Fixed typo 'emCMP' to 'cmEMP'	• Added rule numbers to units of code to verify order • Added Rule 26: debt constrain

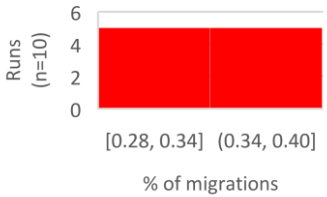
STEP 2. Logical errors– a continuous process during model development since many logical errors (or 'bugs') would prohibit the code from running. A step in the final verification as well where the modeller and programmer checked that all the rules, which by this stage were successfully running, were running as they should.	
Sub-Model	**2a. Logical errors in rule execution:** Checked ODD+2D rules alongside code for accuracy of code logic (i.e., rules doing what they should be). Checked the console logs and data files for small groups (~10) of baseline scenario runs for any anomalies in property values, agent processes, or events/outcomes.
1	• **Rule 3**: Removed obsolete 'low wealth' modification to motivation and updated to no change. This was lingering rule logic in the code from previous versions. • **Motivation modifier values:** Updated model rule documentation (in the ODD+2D) to match the new values in the code which were adjusted while playing with the parameter space during programming to ensure steady fluctuations to motivation – these are revisited in verification Step 3 and calibration.
2	• **Rule 9:** Added a condition to the rule to ensure that the destination offers match for a family-recruiter offer combo. • Solicited migrant offer rule: migrant only gives employer as part of offer if there is a vacancy. • **Rule 11:** Added a condition where Thai-Document-Brokers could not be added to planning networks until the migrant is at destination. • **Rule 12:** Model erroring out for migrants getting a passport with no other plans – reason being an error in the logic of Rule 12 that was stopping migrants from choosing their own destination without an offer which means they would go on to get passports but then have no where to go next. • **Rule 13:** Recruiter was only being added to migration network and not transferring plan properties.
3	• **Rule 18:** The transit plan 'findSmuggler' value was not being replaced with the smuggler's ID which created an intentional 'looping' for some migrants.
4	• **Rule 25a:** Completion rate condition had opposite comparison function – was 'greater than' should be 'less than' • **Rule 25a:** When Employed-Migrants get a work permit they must also get a passport if they do not have one • **Rule 25b:** Preference condition was using the wrong indicators (i.e., indicators for preference being met when it should be *not* being met) • **Rule 25c:** Preference 'or' function should be an 'and' function for the *proximity* and *sector* preference • **Rule 27:** Error in modulus function for determining 180 time-step conditions

STEP 3 – Expected outcome alignment & artefacts – sequential four-staged process (after each sub-model) to explore the events (3a), dynamics (3b), and outcomes (3b) of simulation runs, identify artefacts, and address any unintended model assumptions (3c). Observations from 3a & 3b informed model changes and calibration. We re-executed the Step 3 process three times to check the impact of the changes/calibration to the verified elements and outcomes.

Sub-Model(s)	**3a. Over- / under- firing rules:** Checked frequency of rules / constraints being executed.	**3b. Outcome alignment:** Checked dynamics and frequencies of select outcomes.	**3c. Artefacts:** Reviewed 3a, 3b, and run outcomes (see *Results – Observations*) to check some of the model assumptions in action.
1	Financial shocks:   Constraints: Low, average, and high % of migrants executing constraint, compared across runs: low / avg. / high low wealth: 0% / 0% / 0% hi. wealth: 0% / 0% / 0% low motiv.: 35% / 38% / 40% hi. motiv.: 0% / 0% / 0%	Average migrant attributes: Range for 10 runs' low, average, and high attribute averages: motiv.: low 0-0 / avg. 0.18-0.21 / hi. 0.80-0.81 wealth: low 0-0 / avg. 0.02-0.02 / hi. 0.06-0.10 Migrant states & migration plans:  	**Financial Shocks:** According to the 2017 Myanmar Living Conditions Survey (MLCS), ~16% of the population was affected by 1+ 'idiosyncratic' shock (i.e., household or individual, not regional) and ~45% of households experiencing a shock then 'acted' in response to gain livelihood (borrowed money, 'other') (260). We consider 45% of 16% to be a proxy estimate for households that might experience a financial shock *and* be inclined to 'act' in a year (~7.5%). However, since the simulated financial shock causes a relatively large decrease to wealth (30%) and migration is only one action that can be taken, we aimed for a more conservative estimate. It is difficult to estimate but we feel it is reasonable to assume that 12-15% of households experienced at least one of these shocks in a 5-year period with some experiencing up to 5 in a run (~1 per year). **No changes made.** **Low motivation constraint:** Low wealth, according to the MLCS, usually encourages individuals to migrate domestically and discourages them from migrating *internationally.* The model rules reflect this by decreasing the motivation to migrate for households in the lowest wealth bracket (bottom 25%). If wealth does not change, then this repeating decrease to motivation triggers a 'low motivation constraint', which is expected. It would take a change in family wealth to stop this de-motivation and thus constraint. This was assessed to be appropriate since it is unlikely that social influences would be enough of a motivator to drive international migration in the poorest household brackets as these households are more likely to migrate domestically for work before going abroad (260). **No changes made.**

		Pathways (n) low / avg. / high all: 0 / 0 / 0 null: 102 / 115.7 / 128	**Households with 'planning' migrants:** The MLC Survey reports that 7.5% of households are receiving remittances from family abroad. This is likely to be significantly underestimation of the true total of international migrants from Myanmar as this does not indicate multiple migrations from one family, whole families that migrate abroad (i.e., no remittance being sent), or migrants that cannot or choose not to send remittances. At this stage in the model the percentage of households with a migrant abroad is close to triple the estimate which is a way to account for the 'uncounted' groups and buffering this total for 'drop out' at future stages of the mode. **No changes made.**
	3a. Over- / under- firing rules.	**3b. Outcome alignment.**	**3c. Artefacts.**
1-2	Documentation:   Constraints:	Average migrant attributes: Range for 10 runs' low, average, and high attribute averages: low / avg. / hi. motiv.: 0-0 / 0.19-20 / 0.80-0.81 wealth: 0-0 / 0.02-0.02 / 0.06-0.08 Migrant states and migration plans: 	**Percentage of pre-migration documents (passport and work permit):** The percentage of migrants with a passport or work permit was significantly higher than what empirical data suggests. Upon further inspection of the rules for accepting migration offers we noted that having a 'condition' around the offer having an employer (before applying preferences) meant that most migrants were choosing recruiter offers since they *always* have employers, which meant getting documents. This was over representing the formal documented choices. We removed the 'employer' condition for all migrants and instead added it as a specific *preference* (i.e., the preference for an offer with guaranteed employment) for some migrants. This reduced these pre-migration document figures significantly, but they were still relatively too high. We then revisited how the *work permit* and *passport* preferences worked in the model and compared it to the CHIME study findings on migration influencers. We identified a flawed assumption that work permit and passport were each their own respective preference when in fact migrants preferred 'legal' migration more generally and this could mean one of the two document routes. Condensing these preferences into one (i.e., 'legal') reduced this skew toward pre-migration documentation. In short, removing the blanket employer condition but then adding the employer preference, as well as

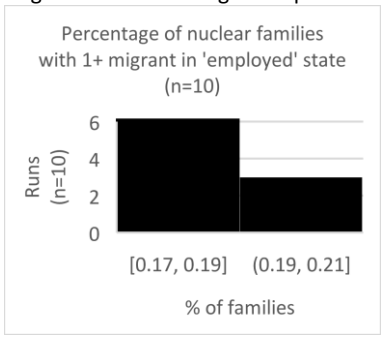
	Low, average, and high % of migrants executing constraint, compared across runs: low: 0% 0% 0% high wealth: 0% 0% 0% low motiv.: 36% 38% 40% high motiv.: 0% 0% 0% low infl.: 0% 0% 0% high infl.: 0% 0% 0%	  Pathways (n) all: 0 0 0 null: 110 132.4 154	consolidating the documentation preference produced documentation patterns closer to the empirical data which suggests the 90% of Myanmar migrants travelling to Thailand do so through irregular routes (82). The slightly higher average across verification runs was accepted to be a reasonable final estimate as there is some evidence of increasing use of documents given increase regularization of migration in the Myanmar-Thailand corridor.
	3a. Over- / under- firing rules.	**3b. Outcome alignment.**	**3c. Artefacts.**
1-3	Border crossing: 	Average migrant attributes: Range for 10 runs' low, average, and high attribute averages: motiv.: 0-0 0.19-0.21 0.80-0.81 wealth: 0-0 0.02-0.02 0.06-0.08	**Unofficial border crossings:** The high rates of pre-migration documents were also causing a high rate of 'official' border crossing. But even after adjusting the documentation related preferences (as described in the row above) the official crossings were still relatively too high. We revisited the two rules that determined border crossing (Rule 13a – Documents, Rule 17 – Border Crossing) and realised that the there was an unintentional assumption that all migrants that preferred legal migration and planned to get documents would be successful (we adjusted the probabilities to account for higher rates of failure or barriers. The remaining imbalance in border crossings we determined might have to do with the disproportionate rate of recruiter offers and 'MOU pathways' (described below).

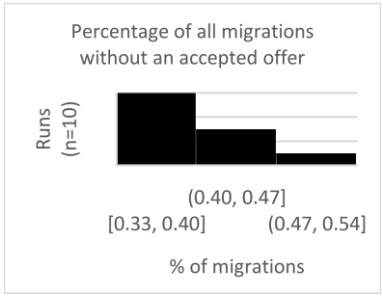


Constraints:

Low, average, and high % of migrants executing constraint, compared across runs:			
	low	avg.	high
low wealth	8%	8%	9%
hi. wealth	0%	0%	0%
low motiv.	36%	39%	41%
hi. motiv.	0%	0%	0%
low infl.	0%	0%	0%
high infl.	0%	0%	1%

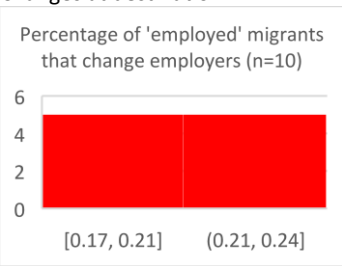
Migrant states and migration plans:



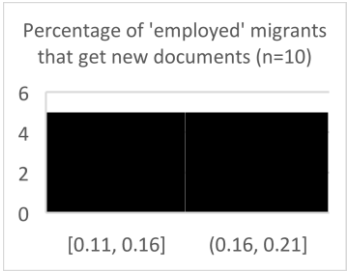


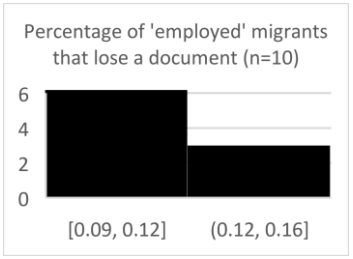
Pathways (n)			
	low	avg.	high
solo	27	33.3	39
family	2	10.5	14
mou	6	9	15
informal	17	27.4	42
null	122	161.5	197

Over-represented recruiter offers: When we first noticed a disproportionate number of 'MOU' pathways we considered two potential artefacts. One was the previously mentioned work permit *and* passport preference which has been fixed. The second was a Recruiter being able to multiple offers into the 'offer options' which meant when migrants chose randomly there were more recruiter offers to potentially choose. To fix this we added a recruiter offer filtering step to Rule 9 so recruiters only put the 'best offer' they had for that migrant in the options.

	3a. Over- / under- firing rules.	3b. Outcome alignment.	3c. Artefacts.
1-4	Changes at destination: 	Migrant attributes:	**Changing employers:** After inspecting the code, we noticed an error with the modulus (logical error identified during artefact checking) affecting how vacancy was calculated. These two errors meant that no (0) migrants were changing employers. We also noted that there was no option for migrants to change employment *before* 6-months and added this into the rules. as option to no pay day rules. Employer vacancy function for change employer was wrong (logical error).

Range for 10 runs' low, average, and high attribute averages:			
	low	avg.	hi.
motiv.	0-0	0.18-0.21	0.81-0.81
wealth	0-0	0.04-0.06	1-1

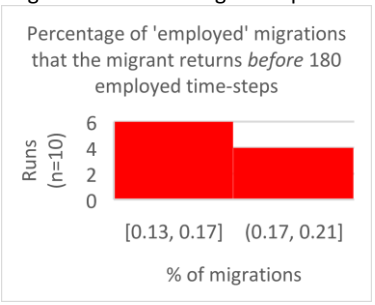


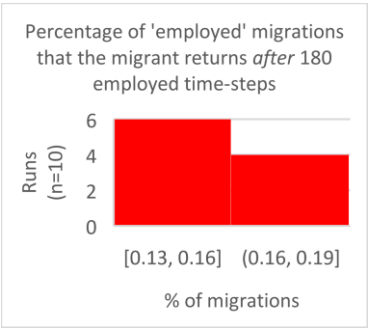


Constraints:

Low, average, and high % of migrants executing constraint, compared across runs:			
	low	avg.	high
low wealth	12%	21%	17%
high wealth	1%	2%	4%
low motiv.	49%%	57%	59%
high motiv.	0%	0%	0%
low infl.	0%	0%	0%
high infl.	1%	1%	2%

Migrant states and migration plans:



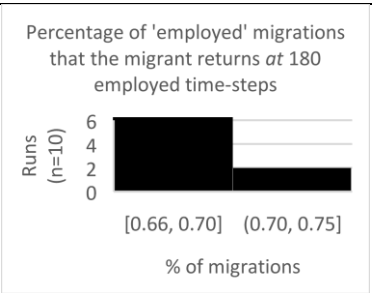


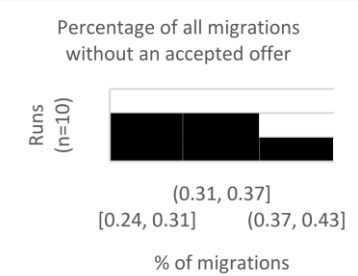
Over-represented recruiter offers: When we first noticed a disproportionate number of regular pathways, we considered two potential artefacts. One was the previously mentioned work permit/passport preferences that were fixed. The second was a Recruiter being able to multiple offers into the 'offer options' which meant when migrants chose randomly there were more recruiter offers to potentially choose. To fix this we added a recruiter offer filtering step to Rule 9 so recruiters only put the 'best offer' they had for that migrant in the options.

Percentage of new documents: The MMSNA found that closer to 15-20% of migrants acquired new documents after arrival. We increased the frequency with which migrants approached Thai Doc Brokers for help with documents in the model.

High wealth attribute and high wealth constraint: In the model we did not account for costs of living at destination which meant migrants were accruing all received pay day wealth instead of a portion of this that remained as 'disposal income' after expenses to keep in wealth (proxy for savings or remittances). Rule 26b now has a discount on the final paid amount to account for living costs.

Null migrations: There was a high number of 'null' migrations (i.e., discontinued migrations). We noted that many migrants arrived at destination without an employer (which can be common in this context) but then were not finding an employer withing the 100-day time-step limit before going home (which would be less likely since most migrants can find some option of employment even if not ideal). We realised the migrants step sizes were too small for them to scout most of the destination area, for example, they were only interacting with 1-2 employers in that 100 time-steps. We reduced the size of the destinations where this issue was most common and increased the step size of migrants when they were in an 'employment seeking' stage of their migration at destination.





Pathways (n)			
	low	avg.	high
solo	38	51.8	69
family	23	38.4	68
mou	15	38.5	54
informal	39	58.6	94
null	186	263.2	367

Returning migrants wealth: Unrelated to any of the outputs we explored, in considering the wealth of migrants at the point of their return, we realized this wealth needed to be distributed amongst their nuclear family to represent an increased shared wealth (new home, new business, family savings) instead of the returned migrant retaining the wealth. This was for two reasons, 1) it is more true to the empirical phenomena of migrants bringing wealth home *to* family not just for their own individual gain, and 2) this meant that if the migrant completed another future migration their was not a 'false' roll-over savings they had which might cause them to return home quite quickly even if they had not made a significant profit from that current migration yet, as they would be referencing the residual wealth from the first migration.

MOU pathways: MOU migration pathways were still over-represented in the pathway distributions, which we identified as the result of two additional artefacts to the ones describe in the previous verification stage on 'recruiter offers'. The artefacts were: 1) recruiters' vision was larger to represent more reach but combined with their many links and movement around the populated Yangon sub-area this may have been contributing to 'too many' accepted recruiter offers; and 2) the proportion of links between different agents and recruiters were dominating the intermediary network and therefore extending the recruiters' reach via these networks. We reduced the recruiter vision to equal the other intermediaries' vision, we added a filtering stage to a recruiter's offers to find the 'best offer' they would make to a migrant and contribute only *one* offer to the migrants' options, and we reduced the linked between Facilitators and Recruiters (from 50% to 25%) and between Myanmar Document Brokers and Recruiters (from 25% to 10%). These changes and calibrations all produced a distribution of MOU pathways closer to the empirical evidence.

A.8.4 Sensitivity Analysis

For the sensitivity analysis (SA), there were nine combinations (SA1-SA9) of the two-factors (**migrant preferences** and **intermediary-intermediary link frequencies**). Each combination was simulated for 10 runs, using the same random seeds across SA1-SA9. We outputted averages and ranges of model outputs to compare the sensitivity of these outcomes to changes in these model attributes. The SA two-factor combinations and key observations are detailed in the main text of the paper. Figure 64 presents the full group of all SA graphical outputs.

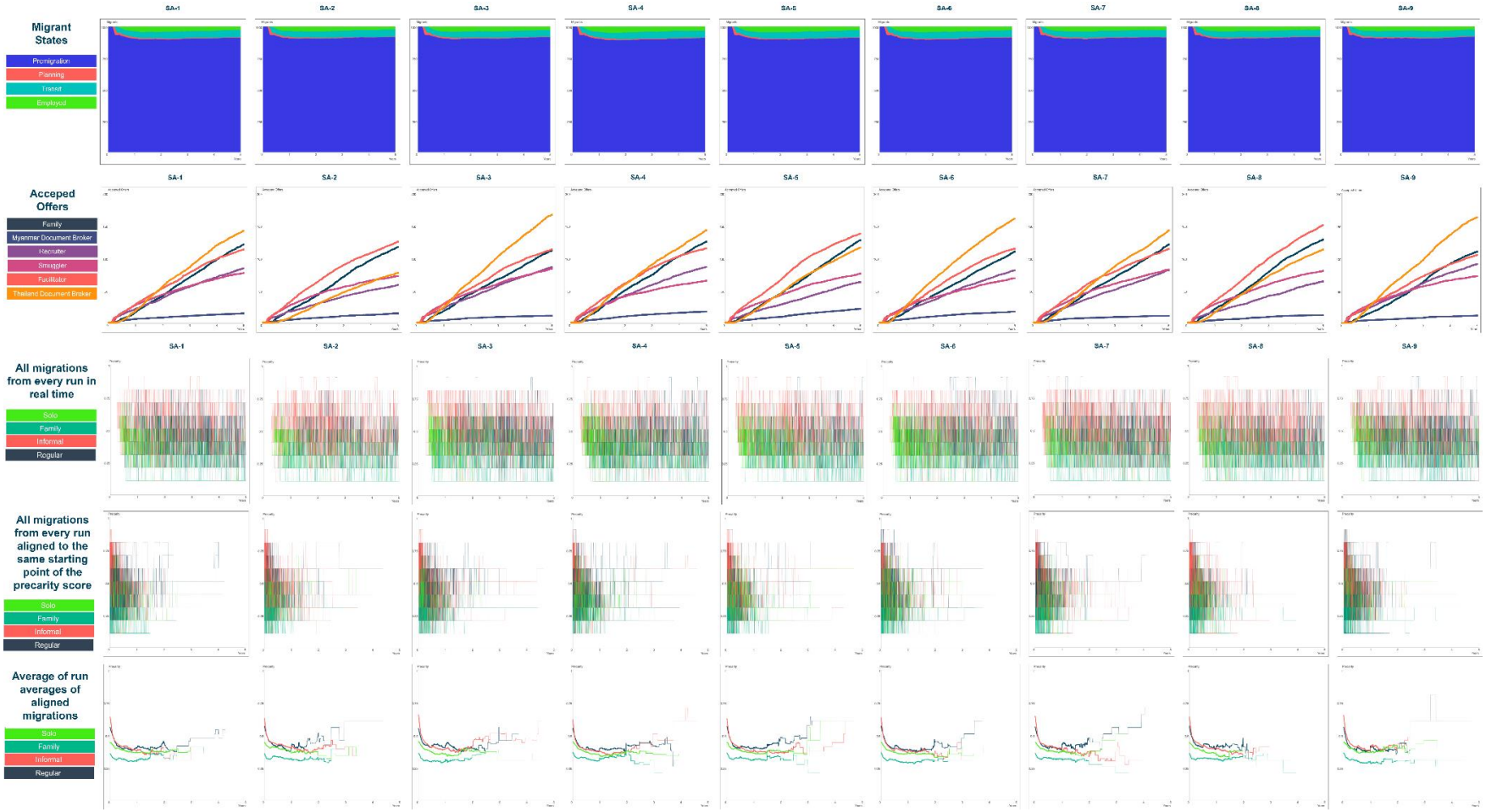


Figure 64. Sensitivity analysis outputs

530

A.9 Research dissemination

Table 61 details the research outputs I have completed or contributed to during my doctoral studies that are directly relevant to my thesis topic.

Table 61. Research outputs during doctoral studies

Contribution	Date	Format
The UCL–*Lancet* Commission on Migration and Health: the health of a world on the move. (see Appendix 1)	Jan-18	Paper
Global Migration Crisis Debate hosted by the London International Development Centre at London School of Hygiene and Tropical Medicine.	Nov-19	Poster
Hargreaves S, Rustage K, Nellums LB, **McAlpine A**, Pocock N, Devakumar D, Aldridge RW, Abubakar I, Kristensen KL, Himmels JW, Friedland JS, Zimmerman C. Occupational health outcomes among international migrant workers: a systematic review and meta-analysis. Lancet Global Health. 2019;7(7):e872-e882.	Dec-19	Paper
Migration Methodologies Workshop hosted by the Asia Research Institute at the National University of Singapore. [Workshop pending due to Covid-19]	Mar-20	Workshop
McAlpine A, Kiss L, Zimmerman C., *et al.* Agent-based modelling for migration and modern slavery research: a systematic review. Journal of Computational Social Science. 2021;4,243–332.	Aug-20	Paper
Preliminary results from MMSNA study presentation to Freedom Fund (collaborative partner and funder for thesis) and their partner and funder, Humanity United.	Jan-21	Presentation
Thesis methods and aims presentation, *Engage@Turing* Student Showcase, The Alan Turing Institute.	Feb-21	Presentation
McAlpine A, Demarest L, Zimmerman C, Kiss L. Visual network tools for mixed methods complex systems research: lessons from a study with migrants. 2021. Submitted to: *Journal of Mixed Methods Research*	Under review	Paper
McAlpine A, Demarest L, Kiss L, Zimmerman C. Labour migration intermediaries, networks, and pathways in the Myanmar-Thailand corridor: a mixed methods social network analysis study. 2021. Submitted to: *Social Network Journal*	Under review	Paper
McAlpine A, Demarest L, Kiss L, Zimmerman C, Chalabi Z. Migration networks and pathways into precarity in the Myanmar-Thailand corridor: an agent-based model. 2021. Plans to submit to: *Journal of Artificial Societies and Social Simulations*	Pending submission	Paper

A.10 Post-doc plans

Alys McAlpine will be starting a post-doctoral position as a Senior Research Fellow in Migration, Violence, and Complexity at the Institute for Global Health based at the University College London. This post is part of a 12-month ESRC-funded research methods innovation grant that aims to explore the use of complex systems simulations to inform and design violence prevention interventions, including labour exploitation prevention.

This project will develop interdisciplinary research methods at the intersection of complex systems, violence, public health interventions, and data visualisation. We aim to evaluate the use of dynamic complex systems modelling to develop interventions for hard-to-reach populations affected by human trafficking and conflict-related violence. The project will address the following questions: What contributions can these novel methods make to the global response to human trafficking and conflict-related violence? How can evidence-based, accessible and visually powerful complex systems models inform decision-makers working on interventions?

More information on this ESRC-funded project can be found here.