

LONDON
SCHOOL of
HYGIENE
& TROPICAL
MEDICINE



Resilience to shocks in national vaccination delivery systems

From analysis of shock effects to resilience-
strengthening intervention approaches in Lebanon

Sharif Adel ISMAIL

**Thesis submitted in accordance with the requirements for the
degree of Doctor of Philosophy of the University of London**

December 2022

Department of Global Health

Faculty of Public Health and Policy

LONDON SCHOOL OF HYGIENE & TROPICAL MEDICINE

Funded by the Wellcome Trust (grant ref 215654/Z/19/Z)



London School of Hygiene & Tropical Medicine
Keppel Street, London WC1E 7HT

T: +44 (0)20 7299 4646

F: +44 (0)20 7299 4656

www.lshtm.ac.uk

DECLARATION OF OWN WORK

All students are required to complete the following declaration when submitting their thesis.

Please note: Assessment misconduct includes any activity that compromises the integrity of your research or assessment of it will be considered under the Assessment Irregularity Policy. This includes plagiarism, cheating and failure to follow correct progression and examination procedures.

Please see the following documents for further guidance:

- [Research Degrees Handbook](#)
- [Assessment Irregularities Policy](#)

Supervisors should be consulted if there are any doubts about what is permissible.

1. STUDENT DETAILS

Student ID Number	1806401	Title	Dr
First Name(s)	Sharif Adel		
Surname/Family Name	Ismail		
Programme of Study	PhD		
LSHTM Email (if this is no longer active, please provide an alternative)	sharif.ismail@lshtm.ac.uk		

2. TITLE OF THESIS

Title of Thesis	Resilience to shocks in national vaccination delivery systems: from analysis of shock effects to resilience-strengthening intervention approaches in Lebanon
------------------------	--

3. DECLARATION

I have read and understood the LSHTM's definition of plagiarism and cheating. I declare that this thesis is my own work, and that I have acknowledged all results and quotations from the published or unpublished work of other people.

I have read and understood the LSHTM's definition and policy on the use of third parties (either paid or unpaid) who have contributed to the preparation of this thesis by providing copy editing and, or, proof reading services. I declare that no changes to the intellectual content or substance of this thesis were made as a result of this advice, and, that I have fully acknowledged all such contributions.

I have exercised reasonable care to ensure that the work is original and does not to the best of my knowledge break any UK law or infringe any third party's copyright or other intellectual property right.

Student Signature	Sharif Ismail
--------------------------	---------------

Date	02/12/2022
-------------	------------

Abstract

Although academic and policy interest in health system resilience has grown considerably in recent years, the empirical literature on this topic is small and predominantly focused on effects arising from single shocks. Shocks are also under-theorised in the health systems literature. This thesis helps to address these deficits through an in-depth case study on the childhood vaccination delivery system in Lebanon, a country which has experienced a series of recent shocks overlapping in time and space, including large-scale refugee influx from neighbouring Syria, COVID-19 and a multi-dimensional political and economic crisis. The thesis opens with an overview of the theoretical literature on system resilience from health and a range of other research fields, highlighting insights regarding resilience conceptualisation, assessment and measurement that are of relevance to health systems. Two empirical papers then explore how sequential shocks have affected the vaccination delivery system in Lebanon, identifying independent and interacting vulnerabilities and their effects at multiple system levels, before tracing key system responses. These papers employ qualitative system dynamics modelling (SDM), an approach that maps out causal links between variables and feedbacks contributing, in this instance, to variations in routine vaccination coverage in Lebanon over time. A third empirical paper uses qualitative, thematic analysis to identify governance factors contributing to system responses to shocks over time. Collectively, these studies identify a series of leverage points potentially amenable to intervention, including delays affecting speed of shock recognition and mobilisation of human and financial resources. They also show how resilience-promoting measures introduced following one shock can paradoxically increase vulnerability to later ones. The final study – a realist-informed systematic review – links findings from the empirical work to intervention evidence from the wider health systems literature, to inform a series of policy recommendations for supporting system resilience in Lebanon over the medium-to-long-term.

Acknowledgements

Theses are usually the product of collaborative work involving many contributors, and this volume is no different. I thank my supervisors, Professors Jo Borghi and Karl Blanchet and Dr Sadie Bell for their guidance and support from inception through to completion of the research project. Karl and especially Jo's generosity in helping make links with others working using systems methods, carrying out research on multi-hazards in fields outside health, and health system resilience more specifically, was instrumental in shaping the ideas presented in this thesis. I am enormously grateful to the Wellcome Trust for funding the work, to Professor David Mabey and colleagues in the then Bloomsbury Centre for Global Health Research for showing faith in a research project somewhat outside their normal areas of focus, and to David Andrews, Christina Albertsen, Anusha Rajeswaran, Tambu Agere and Victoria Dela Luna for administrative support throughout.

In Lebanon, I am grateful above all to the many interviewees who generously gave their time to the research project despite often extremely challenging personal and professional circumstances. This work would have been impossible without the support of Dr Fouad Fouad from the American University of Beirut (AUB), a long-time collaborator who acted as my principal research link in Lebanon. Aya Noubani provided essential support during the interview phase. I am also grateful to colleagues in the Epidemiology and Population Health Department at AUB in which I was based for a time in 2020. Finally, particular thanks are due to members of the Primary Health Care Department at the Lebanese Ministry of Public Health for their support, principally Dr Randa Hamadeh and Dr Wafaa Kanaan.

I benefited from extensive methodological and subject-area support from two main sources. Firstly, my advisory committee: Dr Karin Diaconu from Queen Margaret University in Edinburgh, Dr Diane Duclos at LSHTM, and most especially Dr Andrada Tomoaia-Cotisel from the RAND Corporation in the United States. Many others were generous with their time and advice on specific aspects, including Dr Sandra Mounier-Jack and Rachel Cassidy at LSHTM, and Dr Zaid Chalabi at UCL. At the beginning of the research project, I had no prior experience of system dynamics. There were many in the UK and US system dynamics communities who provided advice at key points, particularly colleagues at Queen Margaret University in Edinburgh whose earlier work using system dynamics in humanitarian crises inspired the approach I took.

To my wife and sons for their support over the three and a half years it has taken to complete this work, and their forbearance through the numerous COVID-19-related disruptions: thank you. It is a great regret that we were not able to spend nearly as much time in Lebanon as we had all hoped. I hope better circumstances there in future may enable us to return soon.

This thesis is dedicated to those living in Lebanon – host communities, refugees and migrant communities alike – many of whom have faced extraordinary adversity in recent years. What began as a research project primarily concerned with health system adaptation to population displacement became a much more complex endeavour trying to tease out the effects of (and possible responses to) an unprecedented series of shocks. The answers outlined here, such as they are, can only be partial. As always, any remaining errors or omissions are mine alone.

SAI, December 2022

Contents

Abstract.....	4
Acknowledgements.....	5
Contents	7
List of figures	12
List of tables.....	14
List of abbreviations	15
CHAPTER 1: Introduction	18
1.1 New frontiers in the analysis of health system resilience	18
1.2 Operationalising health system resilience: the value of learning from, and for, humanitarian settings	21
1.3 Vaccination delivery as a “tracer system” for empirical analysis of system resilience.	22
1.3.1 The importance of vaccination delivery in humanitarian settings	23
1.3.2 Factors influencing vaccination uptake in crisis-affected settings	24
1.3.3 The lack of robust evidence on interventions to build vaccination delivery system resilience.....	26
1.4 Interrogating resilience in vaccination delivery systems: methodological approaches	26
1.4.1 The limitations of existing conceptual tools for understanding resilience in vaccination delivery systems.....	27
1.4.2 The value of systems thinking approaches for empirical analysis of resilience	27
1.4.3 Using system dynamics modelling to better understand resilience	28
1.4.4 Methodological approaches for investigating the role of governance in system resilience.....	30
1.5 Addressing knowledge gaps	31
1.6 Aim and objectives for the thesis	32
1.7 Contributions of the thesis	33
1.8 Organisation of the thesis	33
CHAPTER 2: Conceptualising and assessing health system resilience to shocks – a cross- disciplinary view.....	35
2.1 Introduction: framing resilience in the context of vaccination delivery systems.....	35
2.2 Research paper cover sheet – paper 1	36
2.3 Paper 1: Conceptualising and assessing health system resilience to shocks: a cross- disciplinary view	38
2.3.1 Abstract.....	38
2.3.2 Introduction	39
2.3.3 Defining and conceptualising shocks.....	40
2.3.4 Defining and conceptualising system resilience to shocks.....	44
2.3.5 Assessing and measuring system resilience	51

2.3.6 Conclusions	55
2.3.7 Endnotes.....	56
2.4 Identifying knowledge gaps	57
2.5 Chapter summary	58
CHAPTER 3: Research project setting.....	59
3.1 Country profile	59
3.1.1 General characteristics and health profile.....	59
3.1.2 Dimensions of the “compound crisis” in Lebanon	60
3.2 The health sector in Lebanon	64
3.3 Vaccination delivery in Lebanon	65
3.3.1 Governance and delivery arrangements.....	65
3.3.2 Vaccination coverage across populations: what do we know?.....	67
3.4 Chapter summary	69
CHAPTER 4: Methods	70
4.1 Preliminary step: scoping study	70
4.2 Outline of the project	70
4.2.1 Design of the research project.....	72
4.2.2 Selection of, and justification for, chosen outcome measures.....	72
4.2.3 Time horizon for the research project	72
4.2.4 Defining system boundaries	73
4.2.5 Identifying leverage points within systems.....	73
4.3 Study 1: Using system dynamics to explore shock effects and vaccination delivery system responses in Lebanon	76
4.3.1 Rationale for using a qualitative system dynamics approach.....	76
4.3.2 Data collection and management	77
4.3.3 Generation of the Causal Loop Diagram	78
4.3.4 Evaluating the internal validity of the Causal Loop Diagram	81
4.4 Study 2: qualitative exploration of governance, legitimacy and resilience in vaccination delivery.....	81
4.4.1 Theoretical approach	81
4.4.2 Data collection and management	83
4.4.3 Analytical approach.....	84
4.5 Study 3: realist-informed review of interventions to strengthen vaccination delivery ..	84
4.5.1 Rationale for applying a realist-informed approach.....	85
4.5.2 Methodological approach	85
4.6 Ethics	85
4.7 Funding	87
4.8 Chapter summary	87

CHAPTER 5: Exploring vaccination delivery system vulnerabilities and resilience to shocks using Causal Loop Diagrams	88
5.1 Introduction.....	88
5.2 Research paper cover sheet – paper 2.....	88
5.3 Paper 2: Vulnerability pathways in essential health services: analysing the effects of system shocks on childhood vaccination delivery in Lebanon.....	91
5.3.1 Abstract.....	91
5.3.2 Introduction	92
5.3.3 Methods	95
5.3.4 Results.....	99
5.3.5 Discussion.....	112
5.3.6 Conclusion	115
5.3.7 Back matter.....	115
5.4 Research paper cover sheet – paper 3.....	116
5.5 Paper 3: Resilience in childhood vaccination: analysing delivery system responses to shocks in Lebanon	118
5.5.1 Abstract.....	118
5.5.2 Introduction	119
5.5.3 Methods	121
5.5.4 Results.....	125
5.5.5 Discussion.....	137
5.5.6 Conclusion	140
5.5.7 Back matter.....	140
5.6 Identifying system vulnerabilities and leverage points.....	141
CHAPTER 6: Governance and health system resilience in contexts of perpetual crisis – insights from Lebanon.....	145
6.1 Introduction.....	145
6.2 Research paper cover sheet – paper 4.....	145
6.3 Paper 4: Governance and health system resilience in contexts of perpetual crisis – insights from Lebanon	148
6.3.1 Abstract.....	148
6.3.2 Introduction	149
6.3.3 Methods	151
6.3.4 Results.....	155
6.3.5 Discussion.....	166
6.3.6 Endnotes.....	169
6.4 Identifying system vulnerabilities and leverage points.....	169
CHAPTER 7: Strengthening vaccination delivery system resilience in the context of protracted humanitarian crisis – a realist-informed, systematic review	173

7.1 Introduction: background to the review	173
7.2 Research paper cover sheet – paper 5.....	174
7.3 Paper 5: Strengthening vaccination delivery system resilience in the context of protracted humanitarian crisis: a realist-informed systematic review.....	176
7.3.1 Abstract.....	176
7.3.2 Introduction	177
7.3.3 Methods	180
7.3.4 Results.....	183
7.3.5 Discussion.....	201
7.3.6 Declarations	205
7.4 Situating review findings in the Lebanese context: policy implications.....	206
7.5 Chapter summary	210
CHAPTER 8: Discussion and thesis conclusions	211
8.1 Summary of main findings and relationship to the wider literature	211
8.2 Contributions of the thesis	215
8.2.1 Conceptual contributions.....	215
8.2.2 Methodological contributions.....	218
8.2.3 Contributions to policy development and implementation.....	219
8.3 Limitations of the thesis	220
8.3.1 Conceptual limitations	220
8.3.2 Methodological limitations	222
8.3.3 Reflexivity.....	224
8.4 Directions for future research.....	225
8.5 Concluding remarks.....	227
REFERENCES	228
APPENDICES.....	252
Appendix 1: A general introduction to systems methods.....	252
A1.1 Overview of methods for framing the system, and problem, for investigation	252
A1.2 Understanding dynamic change within systems: spectrum of possible approaches	254
A1.3 Justification for the overarching methodological approach for the research project	255
Appendix 2: Scoping study methodology and results.....	258
A2.1 Theoretical approach to problem articulation	258
A2.2 Scoping study methodology	258
A2.3 Scoping study results.....	259
A2.4 Problem definition	270
Appendix 3: Timeline of key events	272

Appendix 4: Introduction to causal loop diagrams.....	274
Appendix 5: Research tools used to support data collection through interviews	276
A5.1 Consent form	276
A5.2 Semi-structured interview topic guides.....	277
Appendix 6: RIQ template for purposive text analysis.....	286
Appendix 7: Tracking saturation through CLD combination and validation.....	287
Appendix 8: Ethical approvals	290
A8.1 LSHTM approval - UK.....	290
A8.2 AUB approval – Lebanon.....	292
Appendix 9: Systematic review – developing a working analytical framework.....	294
Appendix 10: Systematic review – protocol	296
Appendix 11: Systematic review – list of eligible settings and their eligibility periods	303
Appendix 12: Systematic review – sample search strategy.....	305
Appendix 13: Systematic review – data extraction template	308
Appendix 14: Systematic review – quality appraisal template and results.....	310
Appendix 15: Systematic review – results table	312
Appendix 16: Summary of outputs linked to the research project.....	356
A16.1 Published journal papers and preprints directly linked to the PhD research	356
A16.2 Journal papers and preprints supported in part by funding linked to the project.....	356
A16.3 Policy reports supported in part by funding linked to the project.....	357
A16.4 Conference presentations and posters directly linked to the PhD	357

List of figures

Figure 1. The WHO's health system building blocks model in conventional form.	27
Figure 2. Reference mode and 3 putative trajectories for population vaccination coverage in Lebanon in the event of a shock	32
Figure 3. Relationship between the nature of a shock, prior resilience state of the system, and impact.	42
Figure 4. Visual representation of the adaptive cycle applied to a national maternal and child health system.....	49
Figure 5. Simple classification of approach to resilience assessment and measurement. ...	51
Figure 6. Maps of Lebanon.	60
Figure 7. Ten-year trend in the total number of refugees registered by UNHCR in Lebanon since 2010.	61
Figure 8. Top ten countries worldwide at the end of 2018 ordered according to the density of registered refugees per 1,000 inhabitants that they host.	62
Figure 9. Simple schematic representation of key responsible organisations and service delivery pathways for vaccination from supra-national down to local level in Lebanon.	66
Figure 10. Administrative vaccination coverage rates (national) for selected antigens in Lebanon in the period 2010-20.	68
Figure 11. Mapping of studies within the thesis, and the broad thesis objectives to which each sub-study relates.	71
Figure 12. Schematic representation of the process for generating the initial, shared CLD from the analysis set.	80
Figure 13. The dimensions of resilience governance.....	82
Figure 14. Schematic representation of the process for generating the initial, shared CLD from the analysis set.	97
Figure 15. High-level CLD describing the effects of shocks on vaccination delivery in Lebanon.....	100
Figure 16. CLD showing pathways of impact within the vaccination delivery system in Lebanon following the arrival of refugees from Syria.	103
Figure 17. CLD visualising effects arising from the shocks that took hold in Lebanon from autumn 2019 onwards.....	105
Figure 18. CLD visualising effects on both demand and supply linked to the economic crisis.	107
Figure 19. CLD showing pathways of impact within the vaccination delivery system in Lebanon linked to COVID-19 and the economic crisis.....	109
Figure 20. A series of nested pathways influencing demand for vaccination, shown as a series of balancing loops.....	110
Figure 21. A series of interacting loops describing household-level behaviour influencing demand for vaccination through PHCs and private clinics.	111
Figure 22. Schematic representation of the process for generating the initial, shared causal loop diagram from the analysis set of interviews.	123
Figure 23. High-level view of the causal loop diagram.....	126
Figure 24. Tensions influencing the use of mobile medical units (MMUs) in Lebanon over time.....	130
Figure 25. Dynamics linked to the introduction of task-shifting for vaccination delivery in PHCs.	132
Figure 26. Dynamics linking changing perception of need to mobilisation of donor funding, and downstream adaptive responses within the system.	134
Figure 27. Dynamics linked to private clinic integration into the publicly supported system for delivery of routine antigens at nominal cost to patients.	135

Figure 28. Interactions between early responses and later shocks contributing to vulnerabilities in the cold chain.....	136
Figure 29. Conceptual framework for resilience governance.....	151
Figure 30. Schematic representations of key information flows within the vaccination delivery system.....	162
Figure 31. Guiding conceptual framework for the review.....	179
Figure 32. PRISMA flowchart describing the results of the screening and article selection process.....	185
Figure 33. Breakdown of included articles by intervention class and the type of humanitarian context described.....	186
Figure 34. Ten-year trend in the total number of refugees registered by UNHCR in Lebanon since 2008.....	263
Figure 35. Ten-year trend in population-level DTP3 coverage in Lebanon from 2008 to 2017 from the Lebanese MoPH, and WHO/UNICEF.....	264
Figure 36. Ten-year trend in the total number of refugees registered by UNHCR in Uganda since 2008.....	267
Figure 37. Trends in population-level DTP3 coverage in Uganda from 2008 to from the Ugandan MoH, and WHO/UNICEF.....	268
Figure 38. Reference mode and three putative trajectories for population vaccination coverage in each of the case study countries in the event of large-scale population movement.....	271
Figure 39. Illustration of a negative polarity relationship between two variables using standard CLD notation.....	274
Figure 40. Example of a balancing feedback loop.....	275
Figure 41. Saturation curves by variable addition, link addition, delay addition and feedback loop addition for each additional CLD added from the anchor CLD during the CLD combination phase.....	288
Figure 42. Saturation curves by variable addition, link addition, delay addition, and feedback loop addition, for each additional validation interview added beyond the anchor.....	289

List of tables

Table 1. Definitions, terms and concept clusters linked to resilience in the literatures across research fields.....	44
Table 2. System “leverage points” as defined by Donella Meadows.....	75
Table 3. Breakdown of interviews conducted, by stakeholder group and timing – all interviews.....	79
Table 4. Breakdown of interviews conducted, by stakeholder group and timing – study 2...	83
Table 5. Breakdown of interviews conducted, by stakeholder group and timing – paper 2. .	96
Table 6. Breakdown of interviews conducted, by stakeholder group and timing – paper 3.	122
Table 7. Key system responses identified by the main system level of action, and according to the category of response.....	128
Table 8. Mapping system leverage points identified through the thesis against purposeful interventions implemented to support vaccination delivery in Lebanon since 2012.	143
Table 9. Breakdown of interviews conducted, by stakeholder group and timing – paper 4.	153
Table 10. Key themes and codes contributing to the maintenance or improvement of routine vaccination coverage over time in Lebanon, as identified through framework analysis.....	155
Table 11. Mapping system leverage points identified through the thesis against purposeful interventions implemented to support vaccination delivery in Lebanon since 2012.	172
Table 12. Inclusion criteria applied in the selection of studies for this paper.....	181
Table 13. Summary of interventions included in the review, the mechanisms by which these supported system resilience, outcomes and key contextual modifiers.....	190
Table 14. Mapping system leverage points identified through the thesis against purposeful interventions implemented to support vaccination delivery in Lebanon since 2012.	208
Table 15. Mapping system leverage points identified through the thesis against purposeful interventions implemented to support vaccination delivery in Lebanon since 2012.	214
Table 16. Policy recommendations to key stakeholder groups arising from the research findings.	220
Table 17. Qualitative methods for analysis and boundary definition of complex systems. .	253
Table 18. Matrix for selection of appropriate complex systems analysis methods.	255
Table 19. Steps in the scoping review carried out to determine problem definition for the study.	259

List of abbreviations

Abbreviation	Full text
3RP	Regional Refugee & Resilience Plan (Syria Crisis)
ABM	Agent Based Modelling
AFP	Acute Flaccid Paralysis
BCG	Bacillus Calmette–Guérin vaccine
BMGF	Bill and Melinda Gates Foundation
CAR	Central African Republic
CHD	Child Health Day
CJTF	Civilian Joint Task Force (Nigeria)
CLD	Causal Loop Diagram
CSH	Critical Systems Heuristics
DRC	Democratic Republic of Congo
DTP	Diphtheria, Tetanus and Pertussis vaccine
EPI	Expanded Programme on Immunisation
ERP	Emergency Response Plan (for Lebanon)
EWARN	Early Warning, Alert and Response Network (surveillance)
GDP	Gross Domestic Product
GIS	Geographical Information System
GPEI	Global Polio Eradication Initiative
GRISP	Global Routine Immunisation Strategies and Practices
HARP	Humanitarian Assistance Response Plan
HCW	Health Care Worker
HMIS	Health Management Information System
HRP	Humanitarian Response Plan
ICG	International Coordination Group (for vaccine deployment)
IDP	Internally Displaced Person
IPV	Inactivated Polio Vaccine
LCRP	Lebanon Crisis Response Plan
LMIC	Low- and middle-income countries
MCV	Measles-Containing Vaccine
MENA	Middle East and North Africa region

MHT	Mobile Health Team
MMAT	Mixed Methods Appraisal Tool
MMU	Mobile Medical Unit (Lebanon)
MoPH	Ministry of Public Health (Lebanon)
MoSA	Ministry of Social Affairs (Lebanon)
MOV	Missed Opportunities for Vaccination
MR	Measles and Rubella vaccine
NCD	Non-communicable Disease
NGO	Non-governmental Organisation
OCV	Oral Cholera Vaccine
OCHA	UN Office for the Coordination of Humanitarian Affairs
OPV	Oral Polio Vaccine
OTP	Outpatient Therapeutic Programme
P4P	Pay for Performance
PCV	Pneumococcal Conjugate Vaccine
PHC	Primary Healthcare Centre
PPE	Personal Protective Equipment
PPP	Public Private Partnership
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
RCT	Randomised Controlled Trial
RED	Reach Every District (vaccination strategy)
RI	Routine Immunisation
RIQ	Rigorously Interpreted Quotation
RP	Response Plan
SDC	Social Development Centre
SDM	System Dynamics Modelling
SIA	Supplementary Immunisation Activities
SSM	Soft Systems Methodology
UN	United Nations
UNHCR	UN High Commissioner for Refugees
UNICEF	United Nations Children's Fund
UNRWA	UN Relief and Works Agency (for Palestinian Refugees)

VCM	Volunteer Community Mobiliser
VPD	Vaccine Preventable Disease
WASH	Water, Sanitation and Hygiene
WHO	World Health Organisation

CHAPTER 1: Introduction

1.1 New frontiers in the analysis of health system resilience

Research and policy interest in health system resilience has grown rapidly since the West African Ebola epidemic of 2014-16 and especially since the start of the COVID-19 pandemic. The focus of much of the literature has been on considering ways of supporting capacity development in health systems regarded as ‘vulnerable’. The primary goal of this work has been to better enable these systems to absorb or adapt to shocks¹ as varied as epidemics and extreme weather events (1–4). A smaller literature has also considered what might be termed “everyday resilience” in the routine activities of health workers and services to address chronic stressors such as financing and human resource shortages at district or facility levels (5,6). The pandemic has prompted a partial re-appraisal of the extent to which analysis of resilience should extend to *all* contexts, recognising the shortcomings in health systems performance in some high-income settings exposed by the pandemic (7,8).

However, the literature on health system resilience is emergent and contested. First, there is a lack of agreement on the definition of resilience as applied to health systems (9). In this thesis, I draw on the operating definition of resilience put forward by Blanchet *et al* (10); namely that it describes:

“The capacity of a health system to absorb, adapt or transform when exposed to a shock...and still retain the same control over its structure and functions”

In this interpretation of resilience, *absorption* refers to a health system’s ability to continue to deliver basic health services at the same level (in terms of service quality and availability) using the same resources, following a shock; *adaptation* concerns delivery using fewer or different resources, requiring some level of change; and *transformation* refers to the ability to fundamentally change system structures and functions to respond to external challenges.

Lack of consensus on definitions partly reflects the diversity of shock types against which health system resilience has been analysed. These span communicable disease epidemics, climatic events, humanitarian crises and economic crises among many others (11,12).

¹ Different literatures use different terms to describe analytically interchangeable concepts. In the health systems literature on resilience, the general tendency has been to describe “shocks” (in contrast, for example to chronic stressors). In other fields, particular environmental science and disaster risk reduction, exogenous events are more typically described as “hazards”, which can, in combination with underlying system vulnerabilities and other contextual factors, give rise to systemic risks of varying magnitudes. Humanitarians, by contrast, frequently refer to “crises” (variably defined, as material later in this thesis will discuss). For purposes of consistency, this thesis uses the language of “shocks” to describe events that would be more typically be described as hazards or crises elsewhere. These shocks in turn contribute to local, or systemic, risks of different kinds and magnitudes.

However, a hallmark of shock typologies is that they focus primarily on the triggering event. This overlooks the crucial dimension of time. Time matters partly for better understanding the duration over which shock effects may act. For example, many contemporary humanitarian crises are not acute (in other words, lasting anything from a matter of months up to a few years). Many – including the Syria Crisis which this thesis partly addresses – are protracted crises i.e., “those environments in which a significant proportion of the population is acutely vulnerable to death, disease and disruption of livelihoods over a prolonged period of time” (13). Here, then, we can distinguish between the type of discrete, triggering event (the shock) and its consequences which may vary in scope and duration. An appreciation of time also matters for understanding the state of a system when a shock hits. Work within the health systems field has, for example, described a so-called “shock cycle” spanning preparedness, acute phase shock response and longer-term recovery and rehabilitation (14). Different responses are likely in each phase. This thesis uses the unifying term “shock” to capture the range of potential triggering events. It aims to improve, through empirical analysis, conceptual understanding of the diversity of effects shocks can produce on vaccination service delivery systems.

Importantly, existing work has predominantly focused on the effects of single shocks, and/or single dimensions of these (e.g., recession severity in the context of economic crises (15)). There has been very little attention to interactions between multiple, discrete but overlapping shocks. Work in other fields, especially environmental science, has shown how interactions between events (multi-hazards) may produce amplified or even wholly new risks to systems that might not otherwise have arisen (16,17). It also reiterates the observation above that responses to shocks likely depend on a system’s prior state, in particular any pre-existing vulnerabilities. Applying similar analytical approaches may yield particularly important insights for health systems in humanitarian settings where overlapping shocks are often the norm rather than the exception. Achieving greater clarity of understanding regarding the range of shocks health systems may experience, how they may interact with one another, and how and why they generate disruptive (or potentially resilience-promoting) change within them, is nevertheless a key area for further research in *all* settings.

Secondly, although some consensus is beginning to emerge regarding the kinds of attributes that characterise a “resilient” health system, important uncertainties remain. There is, in particular, general acknowledgement that “soft” factors such as governance effectiveness, leadership capability and institutional legitimacy can have a critical bearing on a health system’s capacity to weather shocks (14,18). However, empirical work exploring links between different governance and leadership models and health system resilience is in short supply. We do not have a clear picture of the leadership and governance capacities and capabilities

that need to be developed to support system resilience, nor the sequence in which they should be deployed. These topics were identified as priorities for further research in a recent agenda-setting exercise (19).

Thirdly, practical approaches to health system resilience-building are poorly developed (20). Some of this stems from a lack of clarity regarding the objectives of resilience-building work vis-à-vis, for example, health system support or strengthening (21). Witter and Pavignani distinguish the narrower focus of health system support and strengthening work from resilience-building which, in their view, “entails an intimate understanding of the whole health system, of the determinants of its functioning and of its evolution over time, all framed in the international context that powerfully conditions its prospects” (22). However, applied work on resilience building for health systems has tended to be much more narrowly focused than this definition would imply, and predominantly focused on the health sector. And while some consensus is emerging around the importance of specific strategies including strengthening governance, financing and surveillance systems, bolstering surge capacity and the empowerment of mid-level leadership for long-term system resilience, analysis remains somewhat abstract, and empirical evidence on intervention effectiveness limited (20,23).

A cross-cutting area of contestation concerns assessment or measurement of system resilience. Here, there has been a degree of retreat from early experiments with universal, health system resilience indices as the multi-dimensional nature of resilience has increasingly been recognised (3). The experience of COVID-19 has exposed deep interconnections between systems inside and outside health that seem to have increased vulnerability to the pandemic (or conversely, strengthened it in some settings) (24). Recognition of these linkages has not yet translated into practical methods for resilience assessment and measurement. There is therefore an important gap for empirical research to develop and test health system resilience assessment and measurement approaches – again drawing on insights from other fields where work is more advanced.

Across all of these areas, there is great scope for continued learning from work in other fields on which health system resilience researchers have historically drawn, including environmental science and socio-ecology. Work in these fields consistently emphasises the dynamic nature of resilience, and the value of taking a systems perspective to understanding its drivers (25–28). However, the span of resilience research is now very large indeed and straddles multiple disciplines (29,30). This proliferation of perspectives on resilience results in major challenges of cross-disciplinary synthesis, contributing to the conceptual confusion that now exists in health systems and policy research (9). There is an ongoing need to find ways to ensure that the health systems research community can draw in appropriate insights from

cutting-edge research in other fields outside health to better inform its work. This is a challenge that Chapter 2 attempts in part to address.

This thesis seeks to make an original contribution to research on health system resilience through a focused case study on vaccination delivery in Lebanon. Lebanon has been afflicted by a series of overlapping shocks in recent years, including large-scale refugee movement from neighbouring Syria, COVID-19 and a multi-dimensional political and economic crisis, among others. The thesis seeks to address gaps in each of the areas identified in the preceding paragraphs by:

- Improving conceptualisation of shocks and the empirical analysis of their effects on health systems, drawing in relevant insights from research in other scientific fields;
- Strengthening understanding of drivers of, or contributors to, health system resilience through empirical analysis;
- Exploring the role of governance in contributing to (or undermining) system resilience; and finally,
- Identifying practical interventions to building health system resilience.

The following sections in this chapter explain the rationale for exploring health system resilience in humanitarian settings, and for doing so through the prism of childhood vaccination delivery as an essential health service. Chapter 3 sets out in more detail the features of the operating context in Lebanon that motivated its selection as the case study for this work.

1.2 Operationalising health system resilience: the value of learning from, and for, humanitarian settings

A good deal of what we know about health system resilience comes from research conducted in humanitarian settings. Health systems in these settings demonstrate vulnerabilities but also capabilities across a range of domains including financing flows, governance arrangements and human resource mobilisation among many others, with measurable health impacts as a result (31). This section provides a summary of what we know about the impact of humanitarian crises on health outcomes, and on the operation of health systems, to explain the analytical focus of the thesis.

Humanitarian crises are typically characterised by some degree of breakdown in health system functionality. There is now wide-ranging evidence of the detrimental effects – both direct and indirect – that may result from this, irrespective of the triggering shock. For example, analysis of the effects of armed conflict on mortality and a range of morbidity-related outcomes shows marked declines in many key indicators, mostly as a result of indirect shock effects

(32,33). The population level impact of complex emergencies on nutritional and communicable disease outcomes is also well-documented, and a large part of the rationale for the prioritisation of these intervention areas in the early phases of acute humanitarian responses (34,35).

Differential effects of crises on health outcomes across populations are also well-recognised. These include the somewhat paradoxical observation that the burden of excess mortality tends to fall disproportionately on internally displaced and to lesser degree host community populations by comparison with refugees. Refugees may enjoy better protection, perhaps because of access to support systems through humanitarian response mechanisms that are not available to others (36). They also include – among many other effects – a differential burden of mortality and morbidity for women children and adolescents (37).

A central finding of post-hoc evaluations of responses to the West African Ebola epidemic was that global institutions and local health systems were inadequately prepared for an outbreak of a high-consequence pathogen on the scale seen in 2014-16. Most of these exercises recommended intensive support to vulnerable health systems over the long-term to bolster their resilience to future shocks (38,39). The new focus on resilience-building has been criticised in some quarters as representing an abdication of global responsibilities to health systems in low- and middle-income countries (LMICs) in favour of a “resilience from below” approach that relies more on community resources (40). However, the pandemic has highlighted the extent to which promoting better preparedness and response mechanisms across *all* countries matters. Recent World Health Organisation (WHO) reports have emphasised the intersections between the pursuit of health system resilience and health security on one hand, and universal health coverage on the other (41). But the challenge of supporting system resilience in humanitarian settings remains particularly acute because, in these settings, public health emergencies overlay pre-existing vulnerabilities linked to often chronic instability, poverty and poor access to essential health services.

1.3 Vaccination delivery as a “tracer system” for empirical analysis of system resilience

This thesis uses childhood vaccination delivery as the ‘tracer system’ for empirical analysis of resilience in humanitarian settings. This section begins with an overview of why ensuring robust vaccination coverage in these settings matters. It then outlines some of the major challenges to ensuring optimal vaccination coverage across populations in crisis-affected settings.

1.3.1 The importance of vaccination delivery in humanitarian settings

Childhood vaccination² is one of the most effective public health interventions available and a major contributor to reductions in mortality and morbidity globally especially among children under five (42–46), but vaccination coverage in many crisis-affected contexts is low (47,48). The WHO and United Nations Children’s Fund’s (UNICEF) annual assessments of efforts to achieve universal vaccination coverage show that around 40% of those infants who had not been fully vaccinated with the Diphtheria, Tetanus and Pertussis vaccination (DTP)³ in 2017 lived in humanitarian settings (49). Zero-dose⁴ children lived disproportionately in the African region and fragile and conflict-affected states⁵ in 2019, the last year for which complete data are available (50). We also know that vaccination coverage rates for routine childhood antigens vary between refugees, internally displaced populations and host communities (51,52).

Humanitarian crises are diverse in cause and character but declines in vaccination coverage resulting from health service disruption are broadly recognised irrespective of the crisis type. Large-scale, panel regression analyses have consistently shown increases in vaccine-preventable disease (VPD) mortality and morbidity as a key impact arising from armed conflict (32,33,53). Similarly, population displacement in crises – whether related to conflict, natural disasters or other proximate causes – can be associated with substantial disruption to population vaccination coverage over time (35,48), and may contribute to communicable disease resurgence in these settings (54–57).

Coverage declines are particularly problematic in humanitarian settings because biological and clinical evidence shows heightened risks of communicable disease transmission and poor outcomes in these settings. Underlying population vulnerabilities are key drivers for this. Aside from cramped living conditions and likely reduced access to water, sanitation and hygiene (WASH), nutritional health among displaced populations is often sub-optimal, contributing to increased risk of mortality and morbidity from VPDs (51,52,57,58).

² This thesis focuses on childhood vaccination (i.e. delivery of vaccines as medical products), as distinct from immunisation (the immunological response to vaccination).

³ Coverage of DTP3 vaccination is the standard conventionally used by WHO and UNICEF to assess childhood vaccination coverage.

⁴ “Zero-dose” refers to the proportion of children who have received no doses at all of selected antigens from the WHO-recommended immunisation schedule for that country. Classically this is assessed with reference to first-dose DTP vaccination (DTP1).

⁵ The term fragile and conflict-affected states (FCAS) denotes a group of countries identified as affected by conflict or by institutional or social fragility by the World Bank. This assessment is made on the basis of a series of pre-defined criteria (indicators) which are revised on an annual basis. Further details of the classification and its underpinning methodology can be found here:

<https://www.worldbank.org/en/topic/fragilityconflictviolence/brief/harmonized-list-of-fragile-situations> [accessed 21st September 2022].

1.3.2 Factors influencing vaccination uptake in crisis-affected settings

Crisis-affected settings are challenging contexts in which to deliver essential health services due to a variety of demand and supply side constraints. In understanding vaccination uptake, we may distinguish:

- *Demand* for vaccination: shaped by a range of interlinked factors spanning popular perceptions of vaccine effectiveness, concerns over potential harms, and population characteristics including educational level and household income (42). In crisis-affected settings these generic factors are often overlaid by additional challenges including suspicion of state authorities, and local barriers to service access which, for refugees and other displaced populations, may be significant (59).
- *Supply* of vaccination: spanning aspects of both community access, and facility and health care worker (HCW) readiness to administer products, as well as overarching system features including financing and governance (42). All of these can be subject to profound disruption in humanitarian contexts (60,61).

On the demand-side, a recent systematic review of evidence from LMICs (both crisis-affected and stable) identifies the decision to vaccinate as the product of favourable population attitudes, pro-vaccination norms in society at large, and individuals' or families' perceived control (or self-efficacy) over the process of vaccination delivery (42). These three, normative drivers of demand are underpinned by a host of factors operating at a number of levels. Societal norms around vaccination, for example, may be influenced by factors including population awareness of the effectiveness of vaccination, perceived safety of different products and popular perceptions of need, as well as the views and influence of informal healthcare providers in LMIC settings (62). In crisis-affected settings especially, trust in services has a critical influence on uptake (63,64). A large body of work emphasises the importance of wider determinants of vaccination uptake, including family socioeconomic status, levels of maternal education and ethnicity, and trust in public health services – which among displaced populations in particular, may be low (65).

A key feature of many contemporary crises is a global shift in shelter patterns for displaced populations including refugees away from residency in camps towards informal, urban or peri-urban settlements. Here, services are accessed through national delivery channels rather than parallel refugee health services (66–68). National health information systems often struggle to capture populations moving in this way (69), making it difficult for services to adapt to changing demand patterns (70).

From a broader, supply perspective, crises pose immense challenges to health system functionality. Human resource attrition can be considerable and, in combination with

disruptions to financing and health information systems among many other factors, can seriously undermine service delivery (71,72). Supply chains for vaccinations can be particularly vulnerable, especially given cold-chain requirements to ensure vaccines' immunological effectiveness. Finally, international humanitarian response mechanisms are often poorly attuned to host community needs and longer-term development imperatives. Financing flows from these sources can also be unstable (73,74).

Despite the strong emphasis in contemporary literature on demand-side factors such as vaccine hesitancy in determining uptake, the presence of effective vaccine products means little without robust systems to deliver them equitably, on time, and with their biological viability intact. There continue to be concerns regarding both the under-utilisation of vaccines in crisis-affected settings (47), and the perceived mismatch between underlying population disease risks and the vaccines actually delivered (75). All of these point to significant, and ongoing problems of *delivery* that require robust health system responses.

In light of this, ensuring greater effectiveness of vaccination delivery in crisis-affected settings is now a key priority for global actors in immunisation policy and financing. The 2018 WHO progress report against the Global Vaccine Action Plan (GVAP), for example, highlighted the need for “special mechanisms” to ensure effective immunisation delivery in humanitarian crises (76,77). Gavi, the Vaccine Alliance, issued an expanded Fragility, Emergencies and Refugees policy in 2018 (78), which has recently been renewed. And VPD control outcomes also form benchmarks for two of UNICEF's five core health commitments for children in humanitarian settings (79). However, there is a continuing lack of relevant empirical evidence in crisis-affected settings, including for communicable disease prevention and control (80). This is an important motivator for the methodological focus of this research project on simulation modelling to support *ex ante* policy evaluation (see below).

In the specific setting on which this thesis focuses – Lebanon – there was also strong evidence from preliminary scoping work that supply-side factors including governance, financing and particularly the efficacy and resilience of the cold-chain for vaccine products were major constraints to delivery (see **Appendix 2**). Finally, a detailed assessment of demand-side dynamics affecting vaccination delivery could not be delivered within the research project. A grounded study of demand for vaccination across refugee populations (on which there is very little background literature in humanitarian contexts) would have required extensive fieldwork with vulnerable populations and providers beyond the data collection set out in the following chapters. It would also have required in-depth analysis of determinants of demand well outside the health sector in a way that it would not have been possible to robustly address with the time and resources available for this research project.

This thesis therefore focuses on vaccination delivery systems, defined here as the combination of people, institutions, resources and activities the primary focus of which is to promote immunisation-specific outcomes (81). The primary focus of the empirical work that follows is on understanding supply-side dynamics influencing vaccination delivery system responses to shocks.

1.3.3 The lack of robust evidence on interventions to build vaccination delivery system resilience

We have seen that conceptual work on system resilience in humanitarian settings remains emergent. The evidence base to inform action to improve vaccination system resilience is similarly limited (20). Recent WHO guidance provides a framework for decision-making and implementation for VPD control in acute humanitarian contexts (82,83), but the operational evidence on which this is based derives from a small number of case studies. It also focuses on the acute phase of emergencies with less attention to longer-term, system-strengthening work (84). In the peer-reviewed literature, two large systematic reviews of health intervention effectiveness in humanitarian settings have highlighted the central importance of vaccination campaigns among other interventions in maintaining and boosting coverage in these settings. However, these reviews have also emphasised limitations in both the quality and extent of the evidence to inform action in this area (80,85). Other work focuses on considerations such as modes of engagement with communities, and micro-level interventions including flexible vaccine dosing schedules in areas where access is challenging (47,51,64,86). None of this work, however, explicitly considers ways of supporting system resilience.

Interventions to strengthen vaccine uptake are typically complex, with multiple components. WHO guidance does make some attempt to define packages, or intervention combinations likely to be appropriate for increasing vaccination coverage for high-risk VPDs by crisis type and phase (83). However, existing work is largely silent on key aspects including the relationship between vaccination delivery through national immunisation systems and those established to serve displaced populations in humanitarian crises. It does not address bottlenecks or constraints to effective delivery, or the potential unintended consequences of intervention implementation for system resilience. A key theme of this thesis is to look at the wider system effects (both positive and negative) of multiple interventions concurrently.

1.4 Interrogating resilience in vaccination delivery systems: methodological approaches

This section considers methodological approaches for investigating resilience in vaccination delivery systems and outlines the rationale for using an approach grounded in systems thinking.

1.4.1 The limitations of existing conceptual tools for understanding resilience in vaccination delivery systems

The conceptual tools available to understand factors influencing service delivery in crises – especially as applied to vaccination delivery – are ill-suited to the on-the-ground realities described in the preceding sections. The conventional heuristic for conceptualising health systems is the WHO’s “building blocks” approach (Figure 1) (87). This focuses on core health system functions, namely: governance (and leadership), financing, supply chains, workforce, service delivery and information systems. However, this framework is static and offers no clear sense of how capacities across the building blocks may interlink with one another to influence system behaviour. It also gives little sense of how relationships between these capacities may change over time.



Figure 1. The WHO’s health system building blocks model in conventional form.

Source: (88). Don De Savigny’s 2009 alternative puts people at the centre of this model, by situating populations as the binding element between the six building blocks identified above (89).

While vaccination-specific tools do exist, such as those in the WHO’s Global Routine Immunisation Strategies and Practices (GRISP) (90) and Reach Every District (RED) (91), these share with the Building Blocks approach [i] a focus on static components contributing to service delivery and health outcomes, and [ii] a lack of clarity on how component parts link together in time and space. These and other conceptual limitations have helped spur the development of more dynamic theories of how health systems actually function (e.g. 44), but without specific parallels for vaccination delivery. Finally, these tools have been used as a basis for health system-, and vaccination delivery system-strengthening respectively rather than for resilience-building work. They have also been used principally under the assumption of a more stable and secure operating environment than typically exists in humanitarian settings.

1.4.2 The value of systems thinking approaches for empirical analysis of resilience

This research project employed systems thinking to understand vaccination delivery system responses to shocks. Systems thinking approaches allow for the complexity of relationships

between elements of a system to be unpacked. In contrast to conventional analytical approaches including the building blocks framework, they recognise the importance of changing behaviour in systems over time, and the potential for unintended consequences when new interventions or contextual changes are applied to them (93,94). Importantly, the ability of quantitative systems thinking methods to model system behaviour under pre-defined scenarios offers advantages over qualitative research methods such as case study analysis that cannot meaningfully evaluate system behaviour *ex ante*. In this sense, systems thinking approaches offer clear benefits when considering how to strengthen future system preparedness, especially in humanitarian contexts where uncertainty is high.

Despite growing interest in systems science approaches in health (95–97), and acknowledgement that they have the potential to significantly improve *ex ante* and *ex post* evaluation of policy and programme designs (93), empirical applications of system dynamics in LMICs have been relatively few (62,81,98–106). Only a handful of studies using systems modelling approaches empirically in crisis-affected settings have been conducted (spanning all sectors) (81,107–109) – just one of which explicitly addressed vaccination delivery (81). For resilience specifically, the number of relevant studies is similarly small – to our knowledge, all have employed system dynamics (110,111).

Although there are many different systems science methods (see the fuller descriptions of these provided in **Appendix 1** and Chapter 4), this thesis applies system dynamics modelling (SDM). The rationale for this decision is set out in the next section.

1.4.3 Using system dynamics modelling to better understand resilience

SDM is an applied modelling methodology that offers structured approaches to problem-solving under uncertainty where robust, quantitative data may be scarce. Importantly, SDM relies on close engagement with stakeholders in defining the problem for investigation but also in determining causal relationships contributing to it. SDM models behaviour over time, and is typically used to model aggregate-level, system behaviour,⁶ with an assumption that the basic architecture of the system remains intact over time. Two central assumptions of SDM are,

⁶ The focus of SDM on the aggregate level should not be confused with a necessary focus on macro-perspectives (e.g., at the national level). SDM can be applied to the analysis of micro-level behaviour and system structures at the level of individual agents, although this is less common. The distinctive hallmark of SDM is, rather, the focus on causality and feedback structures within systems.

firstly, that all key system behaviours are endogenously derived, and secondly, that feedback loops⁷ and delays⁸ within the system are the principal drivers of these behaviours (112–114).

There are some variations in approaches to the application of SDM, but the basic steps are well-rehearsed. The initiation point for SDM is the identification of a problem to be addressed – usually summarised using a ‘problem statement’⁹ and accompanying ‘reference modes’.¹⁰ A dynamic hypothesis (a Causal Loop Diagram or CLD¹¹) is then formulated identifying key system variables, and causal links between them, that are thought to explain the behaviour described in the problem statement. This is often based on eliciting stakeholders’ mental models for how a system is structured and how it operates, using qualitative methods. Typically (though not universally), the CLD is then translated into a quantitative simulation model. With appropriate parameterisation, simulation models can be run to test system behaviour under differing scenarios and sets of assumptions (113,115,116).

As outlined in **Appendix 1**, a range of approaches now exist to support analysis from a systems perspective. However, system dynamics has particular advantages over others in:

1. Facilitating mapping of system structure and causal linkages between variables of interest within a system (117);
2. Pinpointing key feedbacks and delays influencing system behaviour over time (113); and
3. Offering a clear set of methodological tools for stakeholder engagement to build understanding of the system and its behaviour (116).

Finally, system dynamicists adopt a pragmatic approach to data gathering, recognising that the primary focus of modelling work is for decision-support. They use stakeholders’ mental models of a system to build causal maps of variables influencing behaviours of interest. They can also integrate a broad range of data types into simulation models to provide support to decision-makers (118). Finally, system dynamics offers valuable insights for designing and

⁷ Feedbacks describe the rules or mechanisms (typically a flow of information or material – such as a flow of money) in which system variables are linked causally within closed loops. They can be balancing or reinforcing. A *balancing* loop is a stabilising feedback that opposes the broader direction of change within that part of the system. A *reinforcing* loop is an amplifying feedback that strengthens the direction of change within that part of the system. Worked examples of each of these are given in **Appendix 4**.

⁸ Delays can, per Sterman, be divided into two broad categories. *Information* delays describe rate-limiting steps within a system influenced by the flow of information from one part of a system to another (with reference to vaccination, these might include the collection and dissemination of surveillance data on communicable disease outbreaks to inform targeting of vaccination delivery). *Material* delays, on the other hand, describe rate-limiting steps affected by the movement of goods (with reference to vaccination, these might include vaccine doses, or consumables to support vaccine administration, for example).

⁹ The problem statement is a written summary of the problem to be addressed.

¹⁰ Reference modes provide stylised visualisations of system behaviour under different scenarios, focusing on a key outcome of interest. They can be helpful in coming to agreement with stakeholders on the problem(s) and outcome(s) of greatest interest to them.

¹¹ A CLD is in essence a causal map, visually representing causal relationships between variables identified to be relevant to the outcome or trend of interest.

evaluating intervention strategies. These can be quantitative – as in *ex ante* evaluation of policy proposals using simulation modelling. They can also be qualitative: scenario techniques may provide *ex ante* inferences about likely intervention effects even if they do not necessarily support quantitative analysis (97).

1.4.4 Methodological approaches for investigating the role of governance in system resilience

As outlined in the section 1.1, analyses of resilience in the health systems literature have typically overlooked the role of power and institutional legitimacy in shaping system responses to shocks, and empirical work on these topics in health is in very short supply (19,119). The socio-ecological literature, on which so much work on resilience across disciplines is founded, is similarly largely silent on questions of power and legitimacy with some important exceptions (120,121). While SDM has considerable analytic advantages over other approaches for the identification of causal pathways influencing system behaviour, there are important limitations to its utility as an approach for investigating system governance, power and legitimacy as contributors to resilience. These limitations are both conceptual and methodological. Principally, they concern system dynamicists' prioritisation of what Richardson terms "the endogenous view": the assumption that all significant behaviour relevant to a problem is caused by feedbacks and time or material delays *within* the boundaries of the system (112). System dynamics models closed systems and emphasises structure. This is not to imply that systems are viewed as deterministic. On the contrary, agents within the system can and do shape its behaviour in a dynamic way, but all such change is driven from within (118,122,123).

Social systems, on the other hand, are open ones with behaviours that may be heavily influenced by actors outside those boundaries, or by environmental factors (124). The focus on endogeneity in system dynamics is a particular limitation in humanitarian settings where contexts are often fluid, governance arrangements are highly contested and there is often a high degree of penetration of domestic systems by international actors whose lines of accountability extend far beyond national borders (125,126). All of these factors complicate formal boundary definition.

For these reasons, this research project incorporated a qualitative study using thematic analysis, alongside system dynamics. The goal of this work was to complement the SDM work with a richer, contextual analysis that considered the influence of domestic and international governance factors including those beyond Lebanon's borders on resilience in the vaccination delivery system.

1.5 Addressing knowledge gaps

This introductory chapter has outlined a series of knowledge gaps concerning health system resilience in general, and resilience in vaccination delivery systems in particular. Specifically, there is a need for:

- Better conceptualisation of system shocks;
- Better understanding of the effects of shocks (both individually and in combination) on vaccination service delivery systems specifically;
- A dynamic theory of how vaccination delivery systems operate, and how they respond to shocks in crisis-affected settings, as a means for improving empirical understanding of what resilience looks like in practice;
- Better understanding of the role of governance in underpinning (or undermining) system resilience;
- Better evidence on policy/intervention strategies to strengthen resilience in vaccination delivery systems in crisis-affected settings over the long-term.

These knowledge gaps informed the working problem statement for the research project, which was as follows:

Maintaining threshold levels of vaccination coverage in the face of system shocks in settings of [protracted] humanitarian crisis is a major policy and programme delivery challenge. We do not have a clear picture of either [1] how vaccination delivery systems operate in these settings and how they respond and adapt to shocks; or [2] policy and intervention strategies that are likely to bring about sustained improvements in vaccination coverage in the face of system disruption, and constantly changing population numbers and structures.

To address the problem outlined above, the research project focused on supply-side dynamics. In particular, it sought to understand system structures and behaviours contributing to trends in population coverage of key vaccinations in Lebanon, as described in the stylised reference modes for the project (see Figure 2). This visualisation maps out three possible trajectories for vaccination coverage following a shock: an “optimal response” scenario in which, following an initial decline, coverage rapidly recovers and continues to improve along the pre-shock path; a “sub-optimal response” scenario, in which some recovery does occur, but is weak; and a “failure” scenario in which coverage levels off at a lower rate than before the shock.

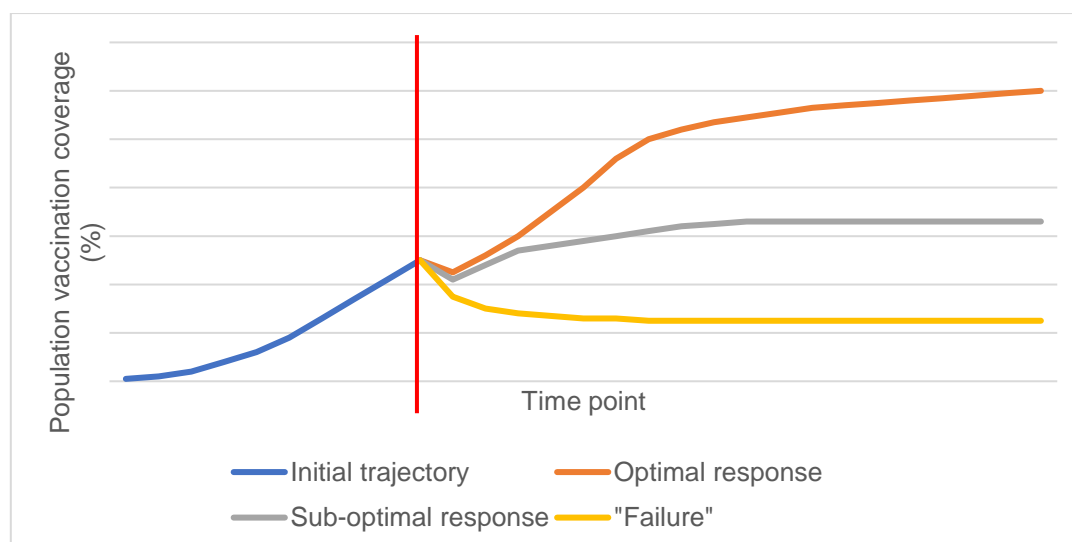


Figure 2. Reference mode and 3 putative trajectories for population vaccination coverage in Lebanon in the event of a shock

This figure assumes that the movement is cross-border (refugees) rather than internal displacement. The vertical red line represents the “shock” point – in this case a sudden population influx.

1.6 Aim and objectives for the thesis

The aim of this research project was to describe and understand the system-level dynamics contributing to disruptions to population-level vaccination coverage in the event of compounding shocks in Lebanon, and to identify viable interventions to support vaccination delivery system resilience in this context.

The objectives of the research project were to:

1. Improve conceptual understanding of system shocks with respect to health systems;
2. Explore the effects of compounding shocks on the vaccination delivery system in Lebanon, and identify real or potential sources of vulnerability within the system in the face of these;
3. Identify specific system pathways or attributes that may explain how and why the vaccination delivery system in Lebanon responded in the way that it did when affected by each of the shocks addressed in this research project;
4. Assess the role of governance and institutional legitimacy in contributing to, or undermining, system resilience drawing on empirical evidence on vaccination delivery in Lebanon; and
5. Identify evidence-based interventions to strengthen vaccination delivery system resilience to shocks, and their potential applicability in the Lebanese context.

1.7 Contributions of the thesis

This thesis seeks to make original contributions to the literature on health system, and more specifically vaccination delivery system, resilience in three main areas. The first of these is conceptual. The thesis aims, through wider literature review, and through empirical case study analysis in a humanitarian setting, to improve our understanding of system shocks and more particularly how sequential or overlapping shocks may interact with one another to influence risks to health systems in general, and vaccination delivery systems specifically. It also seeks to improve our understanding of how these systems may respond to these shocks, and the contribution that governance systems may make to this.

The second area of contribution is methodological. The thesis will provide ‘proof of concept’ for the application of a particular approach to system dynamics modelling for the study of vulnerability and resilience in vaccination delivery systems. It will explore the feasibility of doing so in a humanitarian setting given the particular analytical constraints these impose for research.

The third area of contribution is to vaccination policy. By identifying appropriate, programmatic or system-level interventions, the thesis aims to build the evidence base concerning viable approaches to bolstering resilience in childhood vaccination delivery in humanitarian contexts.

1.8 Organisation of the thesis

This introductory chapter has set out the conceptual framing for the thesis, outlined the central knowledge gaps it seeks to address, and how the research aim and objectives relate to these. It has also described areas in which the thesis seeks to make an original contribution to the literature. The remainder of the thesis is organised into four parts. The first of these is conceptual. Chapter 2 expands on the discussion in section 1.1 by relating themes from the health system resilience literature to contemporary work on resilience in other fields and considers what we might learn from this, with particular reference to questions around shock conceptualisation and resilience analysis. In doing so, it addresses – in part – the first three research objectives set out above. The chapter covers definitions of system resilience, current thinking on key attributes or capacities of resilient systems, and approaches to resilience assessment and measurement.

The second part of the thesis sets out the contextual setting for the empirical work and the methodology. Chapter 3 provides an overview of the context for this thesis, which was Lebanon, describing general features, and the health system- and vaccination delivery environments in-country, as well as outlining key features of the shocks experienced over the

10-year focus period for the research project (2012-22). Chapter 4 then sets out the methodological approach for the research project.

The third part of the thesis brings together two chapters outlining the results of an exploratory, mixed-methods analysis of shock effects and system responses in Lebanon. Chapter 5 describes the results of a qualitative, system dynamics modelling study exploring the effects of overlapping shocks in Lebanon on childhood vaccination delivery, in two empirical papers. The first of these focuses on identifying ways in which the various shocks in Lebanon affected vaccination delivery at different system levels, to address the second research objective. The second paper extends this analysis to look at mitigation approaches and considers the range of responses introduced to help manage the shocks experienced in Lebanon, and their consequences (both intended and unintended). This paper is focused primarily on the third research objective. Chapter 6 then presents an empirical paper testing a conceptual framework describing governance capacities contributing to system resilience, drawing on data on vaccination delivery in Lebanon. This paper primarily addresses the fourth research objective.

The focus then turns towards resilience-promoting interventions. Chapter 7 presents the results of a realist-informed, systematic review of the literature on interventions to strengthen resilience in vaccination delivery systems in protracted humanitarian crises – addressing the fifth and final research objective. Findings from this global review are then related to the operating context in Lebanon, including a discussion of interventions already implemented in that setting.

Finally, Chapter 8 critically assesses research findings and themes running through the thesis, drawing together major contributions of the work and considering implications for future research and for policy.

CHAPTER 2: Conceptualising and assessing health system resilience to shocks – a cross-disciplinary view

2.1 Introduction: framing resilience in the context of vaccination delivery systems

This chapter provides theoretical context to the thesis by presenting a research paper drawing together findings from a cross-disciplinary narrative review on system resilience. The aim of this review was to gather insights with relevance to health systems in general, and vaccination delivery systems specifically, addressing the first three objectives highlighted in Chapter 1. Insights are drawn from fields beyond health including domains such as industrial engineering, environmental science and socioecology. In each of these fields we find evidence of a much more established track record of research on system resilience than currently exists in health systems and policy research.

In particular, the paper addresses four research questions:

- What is a system shock? How is it conceptualised across research fields?
- What is system resilience? How is it defined and conceptualised across research fields?
- What are thought to be the key attributes and behaviours of resilient systems?
- How might we assess or measure system resilience?

The paper makes four main arguments. First, it contends that shocks are under-theorised in health and in the wider literature on system resilience, and that there is a clear need for empirical work in this space. Second, while the paper identifies a growing consensus across research fields regarding key attributes of resilience (or system capacities), dynamic system behaviour is just as important in determining outcomes over time. Recognition of this should spur greater attention to research methods that expose dynamic change within systems. Thirdly, empirical work on system governance for resilience is in short supply in health and in other fields and should be a focus for onward work. Finally, the paper reviews emerging approaches to resilience assessment and measurement across disciplines. It shows that while multi-dimensional approaches blending qualitative and quantitative methods are likely to be needed, dynamic modelling approaches show considerable potential in both eliciting resilience pathways and behaviours, and for resilience quantification.

2.2 Research paper cover sheet – paper 1



London School of Hygiene & Tropical Medicine
Keppel Street, London WC1E 7HT

T: +44 (0)20 7299 4646

F: +44 (0)20 7299 4656

www.lshtm.ac.uk

RESEARCH PAPER COVER SHEET

Please note that a cover sheet must be completed for each research paper included within a thesis.

SECTION A – Student Details

Student ID Number	1806401	Title	Dr
First Name(s)	Sharif Adel		
Surname/Family Name	Ismail		
Thesis Title	Resilience to shocks in national vaccination delivery systems: from analysis of shock effects to resilience-strengthening intervention approaches in Lebanon		
Primary Supervisor	Professor Josephine Borghi		

If the Research Paper has previously been published please complete Section B, if not please move to Section C.

SECTION B – Paper already published

Where was the work published?	Wellcome Open Research		
When was the work published?	13/05/2022		
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?*	Yes	Was the work subject to academic peer review?	Yes

*If yes, please attach evidence of retention. If no, or if the work is being included in its published format, please attach evidence of permission from the copyright holder (publisher or other author) to include this work.

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. (Attach a further sheet if necessary)	I conceptualised the review, with input from JB, KB and SB; performed the literature searches; synthesised material from included articles; drafted the full manuscript; revised the manuscript with supervisory input from JB, KB and SB, and contributions from all other listed authors.
--	---

SECTION E

Student Signature	Sharif Ismail
Date	02/12/2022

Supervisor Signature	Josephine Borghi
Date	02/12/2022

2.3 Paper 1: Conceptualising and assessing health system resilience to shocks: a cross-disciplinary view

Authors: Sharif A. Ismail^{1*}, Sadie Bell¹, Zaid Chalabi², Fouad M. Fouad³, Reinhard Mechler⁴, Andrada Tomoaia-Cotisel^{5,6}, Karl Blanchet⁷, Josephine Borghi¹

Affiliations:

¹ Department of Global Health and Development, London School of Hygiene and Tropical Medicine, UK.

² Institute for Environmental Design and Engineering, Bartlett Faculty of the Built Environment, University College London, UK.

³ Faculty of Health Sciences, American University of Beirut, Lebanon.

⁴ Advanced Systems Analysis Program, International Institute for Applied Systems Analysis, Austria.

⁵ RAND Corporation, United States.

⁶ Department of Public Health, Environments & Society, London School of Hygiene and Tropical Medicine, UK.

⁷ Geneva Centre of Humanitarian Studies, University of Geneva, Switzerland.

*Corresponding author. Email: sharif.ismail@lshtm.ac.uk

2.3.1 Abstract

Health systems worldwide face major challenges in anticipating, planning for and responding to shocks from infectious disease epidemics, armed conflict, climatic and other crises. Although the literature on health system resilience has grown substantially in recent years, major uncertainties remain concerning approaches to resilience conceptualisation and measurement. This narrative review revisits literatures from a range of fields outside health to identify lessons relevant to health systems. Four key insights emerge. Firstly, shocks can only be understood by clarifying how, where and over what timescale they interact with a system of interest, and the dynamic effects they produce within it. Shock effects are contingent on historical path-dependencies, and on the presence of factors or system pathways (e.g., financing models, health workforce capabilities or supply chain designs) that may amplify or dampen impact in unexpected ways. Secondly, shocks often produce cascading effects across multiple scales, whereas the focus of much of the health resilience literature has been on macro-level, national systems. In reality, health systems bring together interconnected sub-systems across sectors and geographies, with different components, behaviours and

sometimes even objectives – all influencing how a system responds to a shock. Thirdly, transformability is an integral feature of resilient social systems: cross-scale interactions help explain how systems can show both resilience and transformational capability at the same time. We illustrate these first three findings by extending the socioecological concept of adaptive cycles in social systems to health, using the example of maternal and child health service delivery. Finally, we argue that dynamic modelling approaches, under-utilised in research on health system resilience to date, have significant promise for identification of shock-moderating or shock-amplifying pathways, for understanding effects at multiple levels and ultimately for building resilience.

Keywords

Health system; shock; resilience; adaptation; transformation

2.3.2 Introduction

Improving understanding of how health systems respond to shocks – such as infectious disease epidemics, armed conflicts or climatic events – has become a pressing issue. The West African Ebola outbreak in 2014-16, and more recently the coronavirus disease 2019 (COVID-19) pandemic, have spurred interest in health system preparedness, shock responses, and ways in which resilience to future events might be enhanced (4,7,127). There is also a strong imperative for transformational change in health systems to bolster future resilience to climatic events given that the health sector is the fifth largest emitter of greenhouse gases globally and potential vulnerabilities to climate-related shocks are both substantial and rising (128).

Efforts to strengthen resilience must recognise that health systems are not simply the side-by-side collection of “all organizations, people and actions whose primary intent is to promote, restore or maintain health” as stated in the original World Health Organisation (WHO) formulation (129). Relationships between system elements at all levels from citizens to international organisations, and across sectors (beyond health) are fundamental to the functions that health systems perform and to achieving health outcome improvements (24,129,130). Risk-based approaches that have been a mainstay of preparedness and response work to date assume some predictability in both shocks and system responses; they also prioritise stability and control within structures that are conceptualised in hierarchical terms (131). By contrast, social systems – including health systems – are complex. Interdependencies within and between them imply high levels of uncertainty in the response to future events, reducing the utility of probabilistic approaches for managing risk (132).

Resilience thinking offers approaches for better managing uncertainty (133). However, conceptualisations of resilience – and the nature of its relationship to other concepts such as vulnerability, fragility, responsiveness and sustainability – remain under development (9,19,71,134–136), and recent reviews of the health literature have identified a series of limitations (3,9,11,12,137–139) including, firstly, a lack of consensus on definitions of resilience, and a tendency to consider, interchangeably, responses to very different kinds of shock. Clarifying the kind of shock a system faces is important not only in differentiating acute events from the chronic stressors (e.g., workforce shortages) facing many health systems worldwide, but also for understanding the scope of potential shock effects (9). Secondly, existing health systems research emphasises mechanisms for absorbing or adapting to shocks but rarely considers transformational change (i.e., wholesale structural change or goal re-orientation). Thirdly, and relatedly, existing research has engaged only to a very limited extent with health system learning and the contribution this can make to resilience. Finally, all studies and disciplines highlight a need for better tools for resilience assessment and measurement (11,12) including enabling robust appraisal of health system performance and proper targeting and evaluation of resilience-bolstering interventions. Existing health system resilience assessment and measurement tools are index-based rather than dynamic, inconsistent in their choices of indicators and have not been widely evaluated (3,14).

Over the past 20 years, valuable insights regarding resilience have emerged from disciplines, including environmental science, economics, industrial engineering, organisational theory, disaster studies and urban studies, which are relevant for health. This paper draws on recent literature on system shocks and resilience in these disciplines to guide health systems researchers interested in resilience and its measurement. The review considers several aspects of resilience: conceptualisation of shocks, definition and conceptualisation of resilience as well as attributes and behaviours of resilient systems, and approaches to assessment and measurement of resilience.

2.3.3 Defining and conceptualising shocks

There is no consensus definition of system shocks in the literature on health system resilience, but two main areas of research can be identified. On the one hand are studies concerned with immediately recognisable shocks such as pandemics, natural disasters, national or international financial crises and armed conflict (e.g. 19). On the other hand, are studies concerned with the effects of chronic, largely internal stressors (e.g., workforce shortages, payment delays, or policy changes), drawing primarily on insights from local or regional health systems particularly in sub-Saharan Africa (5,140).

Shock conceptualisation in other fields, particularly in socioecological systems (SES – an approach to conceptualising natural systems that links ecological and social or institutional subsystems to better explain the effects of resource management) and in economics, offers insights for health systems researchers in three main areas: [i] the need for clarity on shock intensity and scope, [ii] specifying the relationship between a shock and a system of interest, and [iii] the role of path dependencies in shaping shock effects.

Clarity is needed regarding shock intensity and scope to prevent conflation of truly acute events with long-term stressors or trends that may bring about very different dynamics within a system (potential trajectories following a shock, or series of shocks, are illustrated in Figure 3). In ecology, “disturbances” or “perturbations” encompass the disruptive effects of human activities and sudden climatic changes leading to rapid population loss, among other events (141), and close attention is paid to the duration and intensity of impact (142). Scale effects emerge strongly from work in economics, where the impact of both acute events and chronic stressors (e.g., financial crises or economic recessions, oil price shocks or fiscal policy changes due to geopolitical events) are considered but with an emphasis on effects at multiple geographical scales, especially on regional economies (143–145).

Cross-scale effects are also important in work on “systems-of-systems” (i.e., systems whose elements are themselves sub-systems) in engineering, helping to explain how and why a shock may affect a given system as it does. In this view, component sub-systems are focused on discrete objectives or outcomes, but their activities and behaviours are complementary with other sub-systems within the whole system. For example, subsystems in health could be defined by function (e.g., medicines logistics and supply chain systems, or primary care service delivery systems), or by scale of operation (e.g. local, regional, national). Taken together, these systems-of-systems are capable of tasks that component sub-systems could not achieve individually, but also of generating emergent behaviours in the system as a whole, arising from the activities of the individual sub-systems (146). With respect to shocks, existing literature identifies a spectrum from massive shocks outside the boundaries of a system that disrupt all sub-systems within it, to localised disruptions that affect component sub-systems (and perhaps arise from within them) but not the whole (146,147).

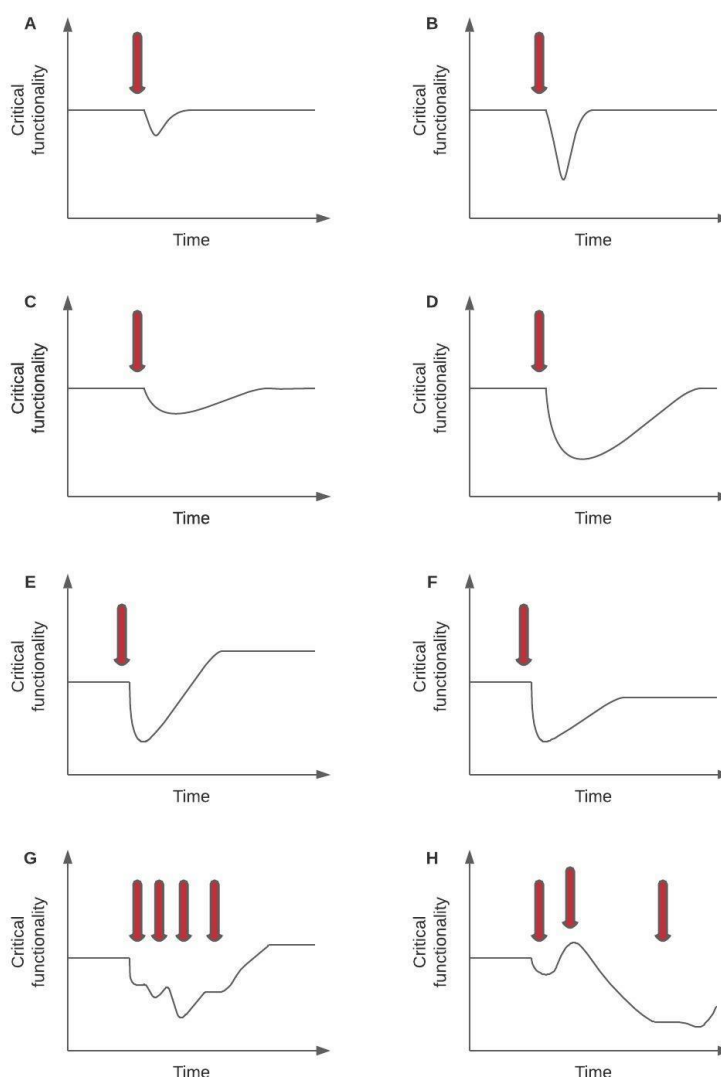


Figure 3. Relationship between the nature of a shock, prior resilience state of the system, and impact. “Critical functionality” here refers to a key outcome measure of interest that captures overall system performance. In panel A, a low magnitude disturbance hits a resilient system, and both the impact and recovery trajectories are tight. In panel B, despite a high magnitude disturbance, a resilient system recovers quickly. In panel C, a low magnitude disturbance hits a low resilience system and recovery is sluggish. In panel D, a high amplitude disturbance hits a low resilience system with severe initial impact and recovery is sluggish. In some instances, a disturbance of this size might be sufficient to cause transformation with either positive (panel E) or deleterious (panel F) effects on critical system functionality, however defined. Panels A-F all show varying effects of a single shock. Panels G and H illustrate potential trajectories in the face of sequential shocks of varying magnitude. In panel G, a series of low amplitude shocks progressively degrade system performance, but recovery is achieved. In panel H, an initially low amplitude shock is followed by a much larger one from which recovery is limited (Figure adapted by permission from Springer Nature from (132), © 2014).

The question of whether a shock should be considered external (exogenous) or internal (endogenous) to the boundaries of the system is a recurrent theme across literatures. Even where shocks are considered exogenous, there may be important relationships with the

system: the size of a disturbance influences risk to the system in the immediate term (alongside other factors such as prior preparedness and vulnerability); and overall effect and impact on recovery trajectory depends on underlying structures and processes. Some work in socio-ecology distinguishes between external drivers of change (the fact of the shock) and internal system variables that are vulnerable to them, and which in turn control the dynamics of other variables within the system. Walker *et al*, for instance, contrast “fast” (variables of core concern in a system that change rapidly) and “slow” (background variables that change much more slowly) system variables that can interact to produce quite different effects, amplifying some shocks, dampening others (148). Contemporary work on systems-of-systems considers both truly exogenous shocks (e.g., external to the system but affecting inputs, and with the potential to disrupt all intra-system elements as a result), and endogenous shocks originating from local disruptions or even emergent behaviours from within the system that have deleterious effects (146).

Finally, a key contention from studies on SES is that shock effects are path dependent (149). The nature and the scope of the response may depend on the phase of what is known as the “adaptive cycle” a system finds itself at the point a shock occurs. Adaptive cycle theory – applied not just to socioecological systems but to social systems more broadly – suggests that systems do not tend to a fixed and stable equilibrium point *per se* but instead move through phases over their life cycle, from rapid growth, through conservation to collapse (“creative destruction”) and finally renewal or re-organisation (150). The implication is that the impact of a shock is likely greater at specific points in the cycle when systems are unstable. Similar arguments regarding the importance of path dependencies emerge from wider research on the health effects of disruptive political and economic shocks, where studies suggest that pre-crisis exposure to health risk factors (alcohol, tobacco consumption etc), as well as the strength of social capital and the robustness of social protection systems are important in explaining differential health outcome trends arising from economic crises as diverse as the Great Depression in the 1930s and post-Communist transitions in Russia and Eastern Europe in the 1990s (151).

In summary, consideration of shock timing, scope and effects at different system levels are all likely to yield useful insights in terms of system elements and pathways influencing resilience. In particular, the prior state or configuration of a system matters, both in terms of vulnerabilities but also the presence of elements with the potential to amplify or potentially dampen shock effects. Finally, health system resilience assessment and measurement approaches may benefit from closer attention to the dynamic effects shocks produce within systems.

2.3.4 Defining and conceptualising system resilience to shocks

2.3.4.1 Resilience definitions and attributes

Table 1 shows the diversity in conceptualisation of resilience across fields, from emphasising persistence and equilibration (e.g., in classical ecology and industrial engineering) through to adaptation, learning and self-organising capability (economics and socio-ecology). In the health systems literature as in work on SES and other social systems, however, there is some consensus regarding key characteristics of resilient systems. These include “hard” attributes such as availability of material and human resources, and the existence of collateral pathways (in health system terms, the existence of multiple mechanisms through which, for example, medical products or health services can be delivered) – echoed in some work in engineering (147). Effective information management is also vital in both engineering and social systems (10,134,147,152), although there is less clarity on best approaches. For health systems, for example, the balance between formal surveillance and softer, more immediate data from human intelligence systems in shaping system responses has emerged as an area of debate in humanitarian settings and in the context of COVID-19 responses (153,154).

Table 1. Definitions, terms and concept clusters linked to resilience in the literatures across research fields.

Field	Summary definition	Conceptual focus(es)	Common, linked terms	References
Health	Varied depending on the tradition (in other disciplines) on which studies draw	Predominantly macro-/meso-level focus on systems, but also a body of literature that addresses micro-/meso-level (organisational) perspectives. Predominantly normative interpretation of resilience, with some exceptions.	Adaptation, self-organisation, emergence (and clustered terms e.g., “collapse”?)	(9,11,12)
(Classical) ecology	System ability to withstand a disturbance while maintaining essential functions and relationships	Equilibration of systems and the speed with which it is possible to return to stable state Magnitude of disturbances No explicit normative judgement on resilience	Resistance, buffer capacity, persistence, robustness	(152,155)
Socio-ecology	System capacity to absorb disturbances and re-organise while undergoing	Learning and innovation are central to resilience in SES systems	Adaptation, learning, innovation, transformability, tipping points	(155,156)

	change in order to maintain the same essential function, structure and feedbacks	Multiple equilibrium states are possible (even desirable) No explicit normative judgement on resilience		
Economics	Process by which economy withstands, adjusts and/or recovers from “market, competitive or environmental shocks”, if necessary by adaptation, to return its prior developmental path or to move to a new, sustainable path	Often regional or local focus for investigation Interest in sustainability (or for purer macroeconomic studies, conventional markers such as GDP) as end-states for “developmental pathways” Dispute over the exogenous/endogenous nature of shocks	Vulnerability, recovery, robustness, adaptability	(144,145)
Development studies	Development resilience as the capacity over time of a person, household or other aggregate unit to avoid and overcome stochastic poverty traps in the face of various stressors and in the wake of myriad shocks.	Predominantly micro-level agency but can be aggregated up to macro-level and increasing emphasis on systemic factors affecting vulnerable to adverse development outcomes.	Adaptation, self-organisation, transformation, role of agency	(157–159)
Industrial engineering	System ability to sustain disruptions without discontinuity in the system’s function (or with as rapid a restoration as is possible if discontinuity does occur)	System behaviour under “normal” conditions offers key insights on behaviour under duress A system has an identifiable, and single equilibrium state Normative interpretation of resilience (i.e., as a desirable state)	Reliability, restoration, (system) failure, safety, efficiency, controllability, (early) detection	(134,155)

Organisational theory	Maintenance of positive adjustment under stress so that an organisation emerges strengthened and more resourceful	Distinction between organisational “software” and “hardware” in explaining resilience Normative interpretation of resilience (i.e., as a desirable state).	Self-organisation, planning, adaptation	(18)
Climate/disaster risk studies	System capability to resist, absorb, accommodate and recover from hazard events and trend after exposure, in a timely and efficient way plus increasingly capacity for transformation	Multi-level resilience (with a large body of literature focusing on micro- and community-level perspectives). Predominantly normative interpretation of resilience.	Anticipate, absorb, cope, recover, persist, transform (the latter largely in research, not yet in implementation), agency	(135,136,157)
Urban studies	Ability of a system to maintain or rapidly return to desired functions in the face of a disturbance, to adapt to change, and to quickly transform systems that limit current or future adaptive capacity	Multi-level focus linking micro- through to macro-perspectives Focus on temporal dynamics Normative interpretation of resilience (i.e., as a desirable state)	Sustainability, recovery, adaptability, re-organisation	(155,160)

“Soft” attributes include networking and connectivity (or collaboration in human systems) (141), key determinants of shifts from one phase to another in the adaptive cycle in SES (30), and of how effectively an industrial engineering system-of-systems operates (161). However, trade-offs (e.g., between efficiency and adaptability in systems, between addressing immediate issues versus structural issues) are important, and networking between elements can undermine system resilience if the degree of connectivity is such that structures become too rigid to enable change (30,162). In social systems, effective governance and leadership are important in maximising the potential of networking and connectivity between the actors of the system for resilience, but empirical studies of resilience governance and system

leadership have been few including in health, although existing health research does identify attributes including legitimacy and knowledge management as important (10,137,152).

2.3.4.2 Resilience as an outcome or as a process?

Resilience can be understood as a process or an outcome, or both. While much work in industrial engineering and socio-ecology, for example, measures resilience directly as an outcome (e.g., by trying to quantify the scale of disturbance a system can sustain and still return to a defined steady state), outcome-focused analyses of resilience in health systems are rare. This perhaps reflects unease about the normative implications of measuring resilience as an end in itself rather than changes in desired health outcomes, but also the intrinsic difficulty of identifying summary measures of resilience given the diversity of health systems functions (9). In this section, we argue that in the absence of broadly accepted summary measures for health system resilience, conceptualizing resilience as a process is likely to prove more fruitful for health systems researchers.

Existing health systems research distinguishes three processes contributing to resilience, drawing on the literature from socioecology: [i] absorption (no structural change occurs; the shock is simply accommodated using existing structures and pathways – sometimes referred to as persistence in the urban studies literature); [ii] adaptation (where certain, circumscribed structural or pathway changes occur to respond to the shock); and [iii] transformation (in which learning is harnessed to fundamentally alter the structure of the system and strengthen it for the future, with or without goal re-orientation) (18,137). The focus in empirical health research has predominantly been on absorption and adaptation, ranging from studies of effects of shocks on critical health outcomes or utilisation of essential services through to changes in service delivery models and coping strategies of health care workers (11,163–165). Studies of transformational change in health systems are largely absent, a deficit perhaps linked to a misperception that resilience theory prioritises stability over the pursuit of just and equitable health outcomes for populations (11,166). Finally, none of this work explicitly links these processes in a conceptually coherent theory of how and why system resilience arises.

Thinking on adaptive cycles in social systems, however, emphasises system learning, adaptation and reorganization, and positions transformability (i.e., the capability to create new structures or reorient system goals when conditions make continuation of existing arrangements impossible) as a fundamental attribute of resilient systems (26). In its original formulation, the adaptive cycle incorporated four stages – system growth, equilibrium, collapse and reorientation – in a feedback loop. Equilibrium was achieved when the maximum potential of a socioecological system was reached, and with the highest level of connectedness between system elements (167). Recent adjustments to this formulation for application to social systems have recognized that connectedness can, *in extremis*, undermine the durability

of a system by reducing flexibility to changing circumstances, but have also emphasized that, if we consider a specific scale of analysis, a system operating at that scale is subject to pressures from elsewhere that may amplify or constrain the potential for change (121,168). An appreciation for multi-scale dynamics and cross-linkages – or “panarchy” – is therefore fundamental to understanding how a system can be both resilient and concurrently show transformational capability (121,156,168–170).

Figure 4 applies this thinking to a health case study: the maternal and child health system in any given country, chosen because this is frequently among the first domains in which health service use and population health outcomes begin to be affected in the event of a shock (171–175). We can think of the maternal and child health system as bringing together population demand and service supply dynamics. In this visualization, the system enters a period of growth (point r) at the initiation point of a new form of structural organization (e.g., due to introduction of systemic reform). There is then an upward trajectory as changes become progressively more institutionalized, population reach increases and service performance (in this case proxied by improvement in the under 5 child survival rate rate) improves. As the figure shows, however, this trajectory is rarely linear and there may be periodic setbacks followed by periods of improvement (black scribble line). At the point of maximal institutionalization of the reformed system structure (K), further growth potential tails off and improvements in under 5 child survival begin to stagnate.

Periodic shocks of varying magnitude may occur at any point along this pathway but, provided they are small enough, these are managed by the system using existing reserves and processes (e.g. surge service capacity, or redeployment of healthcare workers to areas where demand is highest), so that there is a rapid return to the overall upward trajectory for child survival (green line). Beyond a certain threshold, however (grey dashed line), the existing system structure begins to become unstable and rules or pathways governing predominant modes of service delivery begin to break down (yellow line through Ω to α). In systems with sufficient capacity and capability to innovate, there may be a period of rapid testing of alternative approaches, such as new service delivery models or task-shifting for healthcare workers (α), leading – if successful – to a new period of outcome improvement based on a renewed or reorganized system structure and associated behaviours. Pathways to this renewal or reorganisation can be variable, however, with some leading to marked initial declines in child survival (orange lines). Without this, however, further declines in institutional capability to deliver services risk progressive or even sudden declines in under-5 mortality over time (red line).

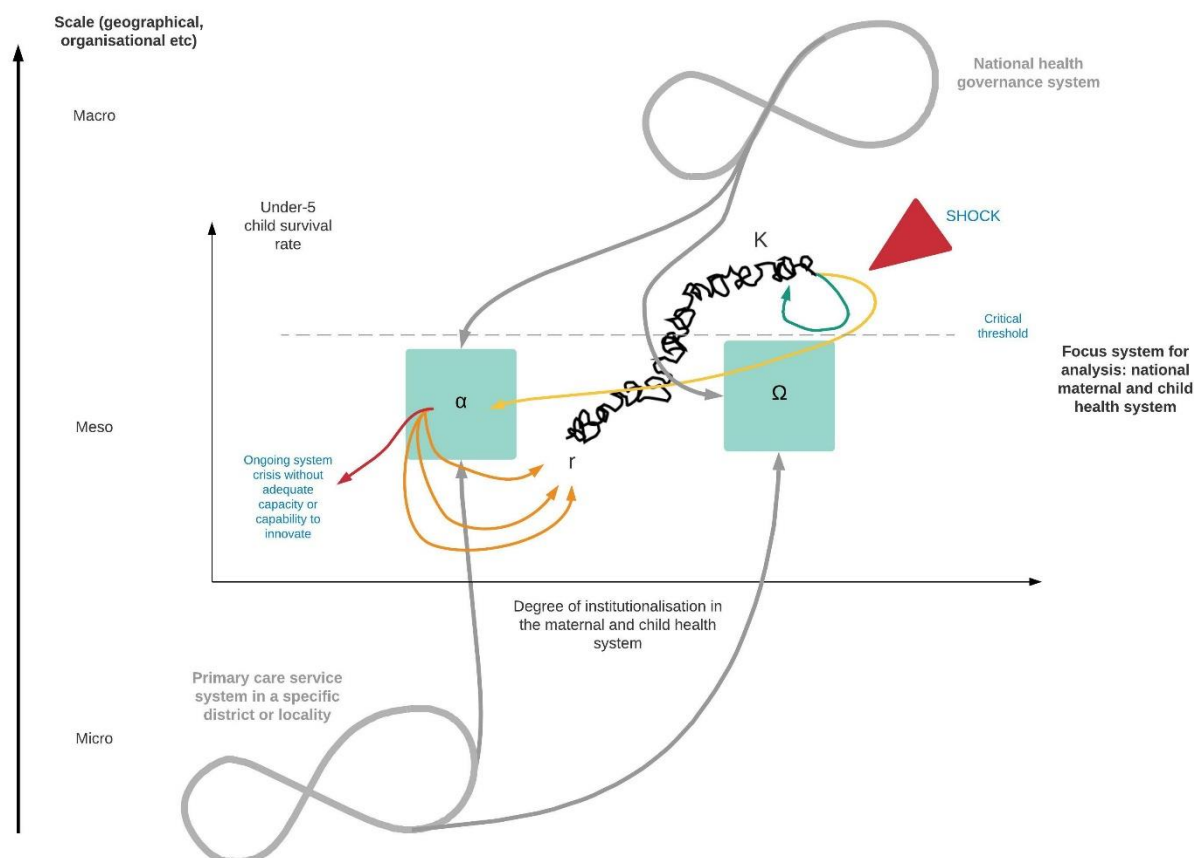


Figure 4. Visual representation of the adaptive cycle applied to a national maternal and child health system. Looking at the focus system in the centre of the diagram, there is steady but uneven improvement in the under-5 child survival rate as system processes and behaviours become progressively more institutionalized, towards an equilibrium point (K). A crisis or shock (red triangle) can be absorbed provided its effects are within a certain threshold, and in this case the system rapidly returns to the general upward trajectory in child survival (green line). If the shock impact exceeds a critical threshold, the system will move towards a zone of instability (Ω) during which structures and processes are disrupted (yellow line). A period of innovation (α) may give rise to system renewal, restructuring or reorientation and return to an upward trajectory (r), but pathways to this can be variable (orange lines). If no innovation occurs, further decline may ensue leading potentially to irrevocable declines in child survival (red line). The key points of vulnerability – and conversely maximal opportunities for change – are α and Ω ; these are also the critical interaction points at which processes in linked systems (in this case the national health governance system at macro-level, and primary care service delivery system at micro-level) at other scales could push the maternal and child health system towards transformation (Figure adapted from reference (168); the original figure on which it draws is licensed under CC BY-NC 4.0, as outlined here: <https://creativecommons.org/licenses/by-nc/4.0/legalcode>).

How a system behaves across this cycle is determined at least in part by pressures from the larger-scale and smaller-scale systems with which it interacts (e.g., geographically or hierarchically) – and this is where the potential for transformative change arises. In work in socio-ecology, environmental science and urban studies, transformation has been conceptualised either as changes in mechanism (e.g., completely new activities, shift in

geographical scale or intensity of an existing activity, or a values-based reorientation in delivery), or changes in system objectives over time and space (176,177). In the modified adaptive cycle in Figure 4, changes in system structure and behaviour arising from within the system alone are likely to be absorptive or at most adaptive; transformative change will typically require resources, or a “push”, from outside the maternal and child health system. These cross-scale interactions have the greatest potential for impact – either positive or negative – at points α and Ω – when the system is unstable. If the shock is national in scope, then there may be critical losses in, for example, health financing or leadership capacity nationally that accentuate the overall impact of the crisis at point Ω on the maternal and child health system. There may also be destabilizing effects at the micro-level, such as loss of income for service users, which reduce service uptake and the likelihood of sustained improvements in under-5 child survival returning. At point α , on the other hand, innovations from linked but smaller-scale systems (e.g. new local-level outreach service models) or macro-scale systems (e.g. mobilization of emergency funding to support service delivery nationally, changes in leadership or governance reforms) may combine in new ways to enable transformative change within the maternal and child health system (168,178).

What specifically prompts transformational change? There is a large body of evidence (e.g., from development studies) demonstrating that shocks can act as spurs to transformative, and positive, change for better long-term outcomes (135). In socioecological and environmental systems, transformations may occur through the combined effect of external pull factors (e.g., to respond to a demonstrable need outside the system) and within-system forces – which may be top-down (e.g. active management) or bottom-up (e.g. collective action) – overcoming opposing forces (27,121). Crucially, resilience is necessary for a transformational path to be maintained once change in this direction begins to occur (27). Transformations need not have positive effects: there is a large literature in ecology on deleterious, even catastrophic ecosystem transformations due to disruption, for example (179). The extent to which a change can be seen as transformative also depends on the scale of analysis. A transformative change in service delivery models at a local level, for instance, is unlikely to materially affect the macro-level structure of a system, though local effects can be substantial (156).

There are three main implications from this work for health systems researchers. First, focusing on resilience processes rather than outcomes liberates resilience thinking from at least some of the normative constraints for which it has been criticised, and offers alternative avenues for assessment and measurement in the absence of broadly agreed metrics or indices for health system resilience. Second, research designs that adopt multi-level perspectives on system responses are much more likely to yield meaningful insights on the sources of resilience (or otherwise) to shocks, and to identify transformational changes that

may occur even in the absence of whole-system reconfiguration. Finally, both of these insights suggest that dynamic approaches that incorporate feedback are likely to be central for future work on operationalizing resilience – the subject of the next section.

2.3.5 Assessing and measuring system resilience

Operationalisation is a particularly challenging area of resilience research. It is helpful to distinguish assessment, which is intended to inform management interventions principally by identifying risks, opportunities and alternative strategies to change (sometimes as a precursor to purposeful transformation); and measurement, which is concerned with early detection of change for situational awareness purposes (155,180). Four main approaches to operationalisation can be identified in the literature (highlighted in blue in the summary Figure 5): the use of [i] qualitative conceptual frameworks; [ii] semi-quantitative indices or metrics of resilience; [iii] conventional quantitative (statistical) approaches; and [iv] systems modelling. In this section, we describe and critically assess the potential of each of these approaches for quantification of health system resilience. Drawing on the material on adaptive cycles presented above, we argue that dynamic modelling approaches are likely to offer the greatest benefit for health systems researchers in future.

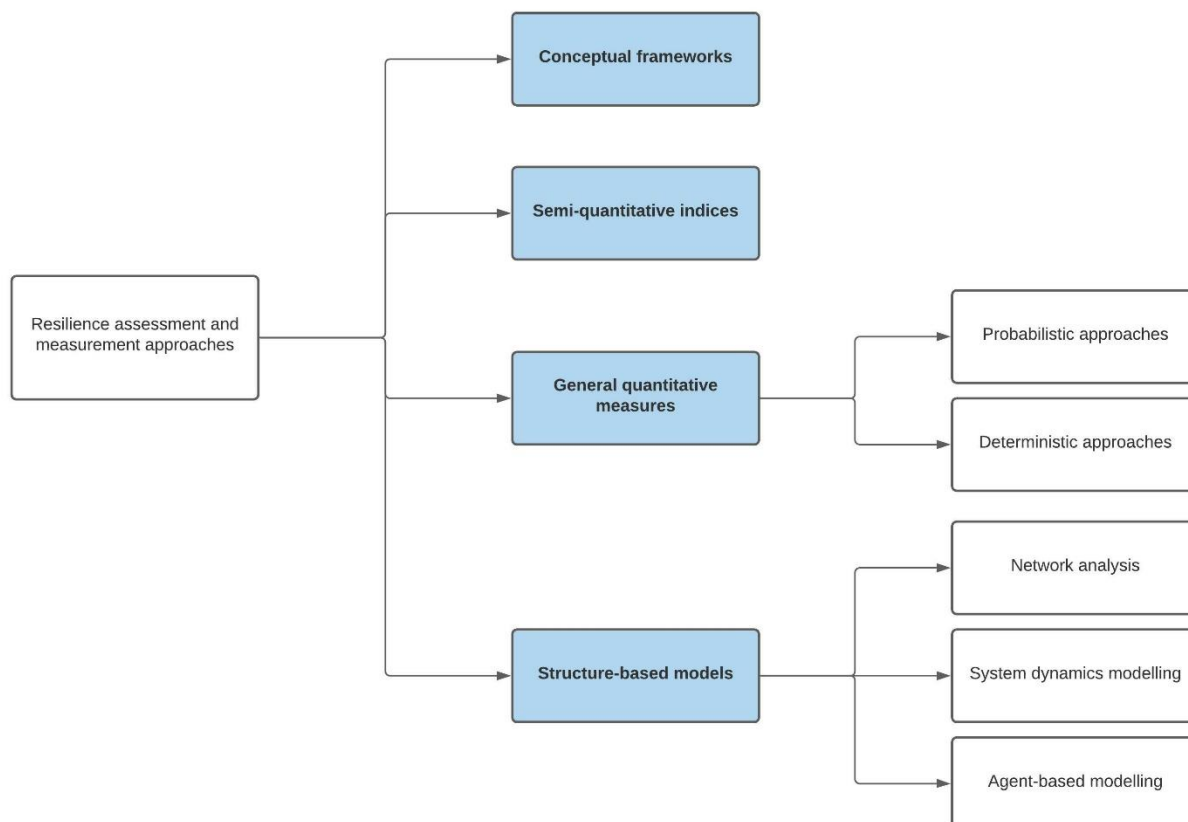


Figure 5. Simple classification of approach to resilience assessment and measurement.

The four broad approaches to assessment and/or measurement considered in detail in the main text of this chapter are highlighted in blue, with specific methodologies highlighted in the right-hand column (adapted from (134), with permission from Elsevier).

2.3.5.1 Methodological approaches in health systems research

Qualitative approaches – in which conceptual frameworks are used to guide investigation of resilience – are by far the most common in health systems research, but even in the empirical literature, few studies use frameworks to guide their analyses (11). Those that do typically reference either [i] a framework inspired by insights from ecology, focused on resilience governance (10); [ii] frameworks linked to the WHO building blocks which consider dimensions of resilience at whole-system level (3,181); or [iii] a framework drawing on organisational theory, but emphasising absorptive, adaptive and transformative approaches to managing chronic stressors (6). Variants of these approaches exist but with few applications in health so far (2), although there is some work applying the absorb-adapt-transform triumvirate to resilience (111,182).

A second strand of health systems research uses semi-quantitative indices in which existing process and outcome measures are repurposed as proxies for resilience (3). Recent work by WHO Europe repurposes common health system metrics (e.g., level and geographical distribution of health sector spending; health worker remuneration and absenteeism; the existence of contingency plans) to build a picture of health system reserve and capacity to respond to shocks that enables iterative monitoring (14). Indicator-based approaches have also been applied to assessment of vulnerability and health system resilience to climatic events, including with a view to *ex ante* “stress-testing” (183–185). These approaches have advantages of simplicity and analytic familiarity but are limited by a high level of abstraction that reduces scope for empirical application (for conceptual frameworks), and because they do not capture dynamic behaviour. The primary means for gathering information on changing system behaviours over time is through iterative indicator assessment, but static frameworks offer no information on pathways affecting these behaviours or on cross-scale effects influencing them (155).

2.3.5.2 General quantitative measures used in other fields

General quantitative measures have been used in socio-ecology, environmental science and industrial engineering to directly measure resilience attributes such as robustness or elasticity but have not to date been applied in health systems research (134,155). General measures have been applied – for example – to assessment of infrastructure resilience (e.g., transport), to measure system robustness, rapidity of recovery after a shock and redundancy among other characteristics. These measures provide an indication of how a system would respond

to a shock but do not account for the probability of that shock occurring in the first place. For this, probabilistic approaches are preferred and have been used to evaluate infrastructure responses in the event of earthquakes, for example (134). In SES, quantitative assessment of skewness or increasing variance from stable points for system critical variables can provide early signs of an impending transformation from one stable equilibrium to another as a disturbance pushes a system closer towards a threshold point, as can critical slowing down (CSD) i.e. increasing delays in system recovery from disturbances as a threshold point is reached (180,186). However, quantitative measures are not always reliable indicators of change, a drawback of metrics-based approaches that has long been recognised in the wider health systems literature (187). The crudity of general measures also means the risks of false alarms can be high, or conversely that other behaviours signalling an impending change are missed; research in SES shows that a sudden, catastrophic shock may, for example, result in transformation without a preceding slowing down (186). Finally, these approaches give little insight into system structure, or dynamic behaviours. Integrative approaches to resilience assessment and measurement that combine quantitative indicator use with mapping and other methods may be better for identifying system attributes contributing to resilience over time (186), but these too do not capture networking or dynamic behaviour.

2.3.5.3 Modelling approaches

Structural modelling approaches provide methods not only for delineating system structure and linkages across levels, but also for identifying leverage points for action that may contribute to preserving, sustaining, and strengthening resilience. They can also be used in a wide variety of ways, from theory generation in terms of the kinds of principles and processes governing system behaviour, through to structurally realistic models that can inform policy or the management of social systems (188). Here, we consider three mixed-methods approaches for exploring system resilience: network analysis, System Dynamics Modelling (SDM) and Agent-Based Modelling (ABM).

Network analysis can help identify components of networks with critical effects on system resilience and linkages between these. There is some – albeit limited – track record of applying these approaches to health system questions. Empirical work looking at the effect of a system shock on managerial decisions in a regional eye health system in Ghana, for example, showed that transformational changes in network organisation reduced overall resilience while simultaneously improving responsiveness to the needs of particular stakeholders in the system – emphasising that resilience is subjectively experienced, and that outcome selection matters (100). Computational modelling of national-level primary healthcare network resilience in Austria showed that following a shock (in this case resulting in large and sudden reductions in the size of the physician workforce) there can be distinct thresholds beyond which the ability

of providers to maintain coverage of essential services is compromised (189). Elsewhere, recent work in engineering has considered the amplifying effects of connections between multiple, related networks (“network-of-networks”) when faced with shocks, especially where there are many feedback and feed-forward connections. This work highlights the need to identify and protect, or grant greater autonomy to, critical nodes that can shape network responses to shocks as a means of bolstering resilience (161). However, network analysis has limited capacity for modelling dynamic behaviour, for which approaches such as SDM and ABM are more appropriate.

System dynamics has been defined as “the use of informal maps and formal models with computer simulation to uncover and understand endogenous sources of system behaviour” (112), and has been applied in a number of empirical studies on resilience in health. Typically, SDM involves production of a qualitative representation of the dynamics contributing to a problem of interest (a causal loop diagram or CLD) with an emphasis on feedback processes, which may then be translated into a simulation model with stocks and flows. The few existing SDM studies on health system resilience have predominantly used CLDs to represent system structure (including important variables, system boundaries and feedback loops), and have highlighted the importance of decentralised decision-making, institutional learning, accurate and timely information flows, and path dependencies in determining the extent to which systems have been able to respond to shocks (110,111,182). Applications of SDM in other fields have focused on participatory engagement in policy development to support system resilience, and quantification of resilience metrics such as robustness, time to recovery from shocks and elasticity, although broader insights from these works are obscured by varying resilience definitions among other limitations (190,191).

ABM focuses on how agency between diverse individuals or institutions, as agents, can give rise to dynamic behaviours. It offers a promising avenue because of its ability to address effects related to network structure and heterogeneity between agents, although there are important trade-offs to consider in terms of time and resource intensity (including computational power) for modelling using ABM by comparison with SDM, which typically models at aggregate rather than individual level (192). In practical terms, applications to both engineering (193) and social systems including to SES have so far been few (194–196). One study applying ABM to analysis of health system resilience was identified for this review, considering local-level service responses to earthquakes in the United States, and more specifically interdependencies between services including health that might affect response effectiveness (197). This study demonstrated significant interdependencies between health service and education providers at local level, suggesting that the integrity of social service provision can be highly vulnerable even to relatively small disruptions.

A particular attraction of SDM and ABM is their flexibility in use, on the one hand, for hypothesis testing and exploration of new modes of working, and on the other in being linked to a greater or lesser degree to empirical data to inform real-world governance and management approaches (188). In reality, both resilience assessment and measurement are likely necessary to give a rounded sense of system resilience spanning structure and dynamics (155,186). Modelling approaches by definition offer heuristics for system behaviour overall, and outputs should be interpreted with reference to empirical or observational research, over and above validation approaches commonly integral to the model development process (194).

2.3.6 Conclusions

What can health system researchers investigating system resilience learn from advances in other fields? Two major domains of resilience research offer the most relevant insights: (i) work on social systems particularly in development, disaster, environmental and urban studies; and (ii) emerging thinking on system-of-systems in engineering. Work in both domains emphasises the importance of cross-scale interactions and transformability – both largely neglected topics in health systems research.

Four general lessons can be drawn from the literature considered here. Firstly, research on resilience should clearly describe shock characteristics such as intensity, duration, geographical scope, and try to identify system elements amplifying or conversely dampening shock effects. Without this, it is very difficult to properly interrogate shock effects.

Secondly, most empirical research on resilience in health continues to use flat perspectives on health system structure (in particular, the building blocks approach) addressing single levels of analysis and taking a uniform view on where system boundaries lie (principally, national boundaries). This framing is problematic for analysis of shocks such as climatic events or armed conflicts that can produce cascading effects at multiple health system levels within and across jurisdictions. The system-of-systems and network-of-networks approaches allow us to frame shock responses very differently, recognising that health systems combine interconnected sub-systems (both sectoral and across geographies) with different elements, behaviours and even objectives. Medicine supply chain sub-systems, for example, likely operate in fundamentally different ways from health governance and accountability sub-systems. As part of the reckoning with the impact of COVID-19, however, there is also growing recognition of the need to consider connectedness with broader societal systems, including economic, environmental and social ones, in bolstering health system resilience to future shocks of global scale (24). The methodological corollary of these observations is the need

for mixed-methods research designs that interrogate resilience at multiple levels and across sectors.

Third, transformability should be considered an integral (rather than incompatible) property of resilient systems. Recent theoretical work applying the concept of an adaptive cycle in social systems reinforces the importance of links between systems across scales, and also provides a new way of thinking about how and when transformational change arises that can, as we have seen, be readily applied to health systems (121,168,170). Work on SES and urban systems also emphasises that, once a crucial tipping point has been reached and transformational change towards a new equilibrium state begins, resilience is a prerequisite for momentum to be maintained and transformation to be realised.

Finally, although approaches to assessment and quantification of health system resilience remain nascent, modelling approaches including network analysis, SDM and ABM have significant potential to advance research in this domain. These three approaches have been applied to a very limited extent in health but can provide valuable insights on critical system elements through which shock effects are most likely mediated. SDM and ABM also capture dynamic behaviour in a way that conventional quantitative approaches cannot, to identify processes underpinning resilience and potential leverage points for intervention. Health systems researchers have an opportunity to lead the advancement of resilience research across fields, through application of these methods.

2.3.7 Endnotes

2.3.7.1 *Grant information*

This work was supported by Wellcome [215654; a Wellcome Trust Clinical Research Training Fellowship to SAI].

2.3.7.2 *Competing interests:*

The authors declare that they have no competing interests.

2.3.7.3 *Data availability*

No data are associated with this article.

2.4 Identifying knowledge gaps

Findings presented in the research paper in section 2.3 highlight a series of knowledge gaps in resilience theory as applied to health systems. Firstly, system shocks are under-theorised. There is a need to better understand the ways in which shocks in interconnected systems manifest their effects within health systems, and how and why effects may cascade in the ways that they do. The prevailing lens for analysing health system resilience in the published literature is national but work in other disciplines strongly suggests this risks missing important regional and local influences on system behaviour. There is clear space for theoretically grounded, empirical work that sets out the pathways by which shocks cause effects at different system levels, and this thesis seeks to directly address this through primary case analysis.

Secondly, while there is growing consensus on general attributes and behaviours of resilient social systems (including health systems), it is apparent that *both* process and attribute-based perspectives matter. Recent work extending socioecological theory on adaptive cycles to social systems offers a wholly new way of thinking about how health systems respond to shocks. It provides a way of conceptualising how cross-scale interactions with other, linked systems at critical time junctures can influence the likelihood of transformational change. This suggests that to better understand health system resilience we need to pay closer attention to *dynamic* behaviour. In other words, pathways, time delays and other behavioural features all likely help to explain how and why systems respond to shocks as they do. This has important methodological implications (see below). A key focus for this thesis will be on identifying dynamic system behaviours contributing to resilience in vaccination delivery using a multi-level approach.

Thirdly, questions concerning system governance are key, but as the research paper findings show, this is a largely neglected dimension of resilience. Recent reviews of the empirical literature on health system resilience show that primary studies focused on resilience governance continue to be in short supply (11). There have been calls for closer examination of the role of governance systems, and of institutional legitimacy in contributing to (or undermining) system resilience (19,119). Work on adaptive cycle theory in other fields also implies very different governance models and capacities to those typically found in health systems worldwide. Recent work on environmental governance building on this theory, for example, emphasises features such as decentralisation in service delivery, disseminated leadership, a culture of encouraging innovation through experimentation, strategic foresight and system-wide learning (168). There is a need to consider what aspirations towards these kinds of attributes and behaviours might mean for health systems where there may be important trade-offs between local autonomy and macro-level oversight (e.g., a tension between vaccination services better tailored to local circumstances vs national product safety

and cold chain integrity requirements for childhood vaccinations). Importantly, there is a need to empirically test the extent to which “ideal type” governance attributes identified in systems outside health can usefully be applied to health systems. The empirical analysis in Chapter 6 addresses some of these questions.

Finally, the paper offers novel insights regarding ways in which resilience can be operationalised. It highlights a growing consensus beyond health systems research that multi-dimensional assessments blending combinations of some or all of the qualitative and quantitative approaches outlined in the review are needed to properly evaluate system resilience. Work in this area as applied to health systems remains emergent. Empirical work that explicitly adopts this multi-dimensional approach to resilience assessment in health remains very limited.

2.5 Chapter summary

This chapter has set out a series of knowledge gaps in resilience theory as applied to health systems that this thesis aims to help address, through primary case analysis. Chapter 3 outlines the geographical setting for the primary data collection for this thesis, justifying the choice of location with reference to some of the themes and policy questions identified in Chapter 1.

CHAPTER 3: Research project setting

In this chapter, I introduce the setting for the research project, which was Lebanon. The primary justification for the choice of Lebanon as the focal case study at the inception of this work in 2018 was that it was home to the highest density of registered refugees in the world and had experienced large and recent spikes in cross-border population movement. Importantly, the principal primary health service access points for refugees (including for vaccination) have for some time been through national vaccination delivery systems rather than through parallel refugee health service pathways. Since the initiation of the study, Lebanon has also experienced at least two further shocks of national scope: COVID-19, and an ongoing, multi-dimensional political and economic crisis. The overlap of these shocks in time and space, and interactions between them, form what has been termed a “compound crisis” (198). Unravelling the effects of this compound crisis on childhood vaccination delivery is a key conceptual focus for this thesis. Key milestones relevant to the thesis are summarised in **Appendix 3**.

3.1 Country profile

3.1.1 General characteristics and health profile

Lebanon is a small country in the Levant region of the Middle East, covering around 10,500 km². Administratively, it is divided into nine governorates and a total of 25 districts (

Figure 6). National population estimates are contested. The confessional orientation of the political system in Lebanon has contributed to the politicisation of population data and no national census has been conducted since 1932 (199). Current estimates range from 4.5 million (the broadly agreed figure prior to the arrival of Syrian refugees in large numbers from 2012 onwards) up to as much as 6 million in 2021 (200).

The most current estimates at the outset of the research project (in 2019) showed that demographically Lebanon was a young country, with some 26% of the population below the age of 15. Life expectancy was comparable with regional neighbours at around 79 years (201). In common with many of its regional neighbours, Lebanon had experienced a partial epidemiological transition so that the predominant source of mortality and morbidity population-wide came from non-communicable diseases (NCD). The risk factor profile for Lebanon broadly accorded with the distribution of disease. High body mass index, tobacco consumption, dietary risks and hypertension contributed by far the greatest share of disability-adjusted life years (DALYs) lost in Lebanon each year and continue to do so today (202). This

overall picture masked some distinct features of the demographic and health profile for recently displaced refugees, however. Displaced Syrians were, and are, younger and poorer than host communities and have lower levels of educational attainment, on average. Most currently reside in inland districts bordering Syria (203–205).



Figure 6. Maps of Lebanon.

Panel A shows the country in global and regional geographical context (© Rei-artur / Wikimedia Commons / CC-BY-SA-3.0 / GFDL). Panel B shows the major administrative (governorate-level) divisions in Lebanon. These correspond to regional focuses for data collection outlined later in this thesis (source: <https://ialebanon.unhcr.org/> - accessed 22nd September 2022).

From an economic perspective, Lebanon was classified as an upper middle-income country by the World Bank at project initiation. However, the most recent publicly available data from this institution indicate a precipitous decline in gross domestic product (GDP) per capita from around \$7,600 in 2019 to \$4,650 in 2020. For the World Bank's 2023 fiscal year, Lebanon was re-classified into the lower-middle income lending group category. These changes can largely be explained by the ongoing economic crisis which is described in more detail in section 3.1.2.2 (200).

3.1.2 Dimensions of the “compound crisis” in Lebanon

Over the course of this study, Lebanon was steadily engulfed by a series of shocks. These shocks stemmed not just from the population movement described above and its long-term implications for service demand. From 2019 onwards, an accelerating economic crisis and linked crisis of legitimacy for public institutions profoundly affected the health service delivery context in Lebanon. The COVID-19 pandemic resulted in wide-ranging disruption including the imposition of a series of national lockdowns and the temporary closure of Lebanon's international borders. Finally, in August 2020 a large explosion in the capital, Beirut, destroyed the national vaccine storage warehouse in the port area (Karantina). These shocks overlapped and interacted in particular ways with profound effects for health service delivery across

populations (206). This section provides a brief overview of each of these shocks. Later chapters will explore in more detail pathways of interaction between them and the implications these have had for vaccination delivery in Lebanon. A timeline of all key events in Lebanon across the study period is given in **Appendix 3**.

3.1.2.1 Population displacement from Syria

The Syria Crisis is the cause of the latest in a long series of large-scale population displacements into Lebanon, with around 825,000 registered Syrian refugees residing in the country as of September 2022, down from a peak of just under 1.2m in April 2015. The bulk of this cross-border movement occurred in a concentrated period in 2013-15. Although some degree of movement continues today, this is bidirectional and in aggregate the overall trend is now towards slow returns to Syria (Figure 7). Precise estimation is, however, complicated by the fact that a large, unregistered refugee population has always been excluded from these numbers, and by the fact that political pressures obliged the United Nations High Commissioner for Refugees (UNHCR) to stop registering new arrivals from 2015 onwards (207).

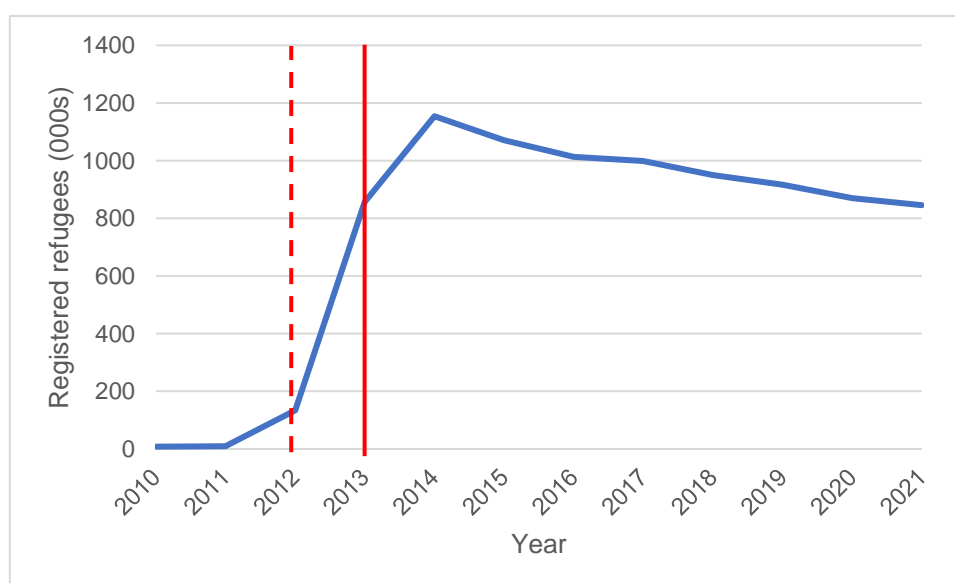


Figure 7. Ten-year trend in the total number of refugees registered by UNHCR in Lebanon since 2010. The vertical red-line indicates the point at which cross-border movement from Syria escalated rapidly – corresponding to one of the system shocks of interest in this study. The beginning of the conflict in Syria is indicated by the dashed vertical line. Source:(207).

There have, in addition, been some 469,600 Palestinian refugees in-country for many years to whom health services are provided by the UN Relief and Works Agency (UNRWA) (208). Taken together, Palestinian and Syrian refugees may account for up to 24% of the Lebanese population (206). According to UNHCR figures, Lebanon had by some distance the highest

density of registered refugees per 1,000 inhabitants of any country in the world in 2020 (Figure 8).

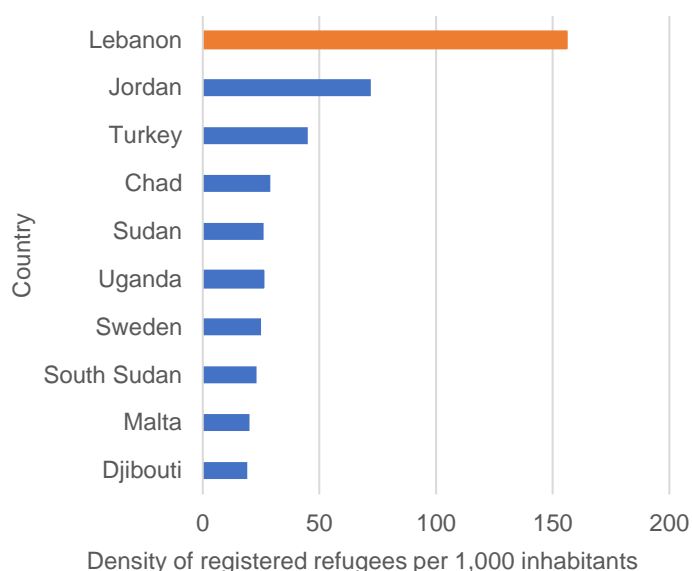


Figure 8. Top ten countries worldwide at the end of 2018 ordered according to the density of registered refugees per 1,000 inhabitants that they host.

Source: UNHCR statistics and (209).

Although Lebanon operated a *de facto* open-border policy towards Syrian refugees between 2011 and 2014, official positioning vis-à-vis the crisis has varied over time. This reflects the politicisation of the crisis response, and especially perceived spill-over effects from the conflict in Syria, as embodied in the Dissociation Policy¹² introduced in 2012 (210,211). Since 2015, there has been a progressive hardening of rhetoric towards Syrian refugees, on which a number of high-profile political figures in Lebanon have sought to capitalise. In May 2015 the government formally requested that UNHCR stop registering new arrivals from Syria (212). Relations between the government and many of the major agencies involved in the response are challenging (213).

The large majority of those displaced by the Syrian conflict who are currently living in Lebanon are scattered across 2,100 formal and informal settlements, and conditions for most are poor. Many of those displaced live in governorates bordering Syria where public service access and quality even for host communities have historically been low. Syrian refugee households in

¹² The Dissociation Policy was intended to enforce neutrality by political actors (many of whom are also armed independently of the state) in Lebanon towards the crisis, ostensibly to prevent them from being drawn in as parties to the conflict in Syria. However, it has also had the effect of providing cover for limited recognition of rights for Syrians (including in the labour market), for whom – as a matter of government policy – no refugee camps can be established.

Lebanon have also been severely affected by the economic crisis. In 2019, some 55% of Syrian households registered with UNHCR were below the poverty line, but the most recent data (for 2021) show that this proportion has increased to 88% despite an increase in assistance from humanitarian actors (214).¹³

3.1.2.2 Political and economic crisis

Instability has been a recurrent theme in the Lebanese political landscape for some time, but this has intensified markedly since autumn 2019. It has occurred against the backdrop of a deepening and multi-faceted economic crisis that the World Bank has described as a “deliberate depression” (215). Historically, the long-range economic picture in Lebanon has been heavily influenced by periods of armed conflict, especially the 1975-1990 civil war, and more recent (2006) conflict with Israel. Reconstruction strategies following each of these conflicts depended on heavy borrowing on international markets and state retrenchment in terms of provision of essential services (216). By the mid-2010s, income and wealth inequality in Lebanon had widened as ruling elites imposed ever increasing rents on residents (217). These were some of the conditions that contributed to the emergence of broad-based protests from October 2019 onwards, calling variously for the fall of the incumbent government to the removal of the entire Lebanese political class at that time.

Economic conditions in Lebanon have deteriorated markedly since autumn 2019. This is due to the historically unusual confluence of three separate economic crises: [i] a large balance of payments deficit affecting the country’s ability to import essential goods; [ii] a fiscal crisis affecting government revenues, and as a consequence, its ability to spend on essential services including health; and [iii] a banking system liquidity crisis with implications for ability of domestic actors to borrow to finance purchases, and for everyday exchange rates (218). The implications for those living in Lebanon have been severe: annual inflation rates (by official estimates) exceeded 200% in early 2022;¹⁴ UN estimates suggested that the proportion of the population in multi-dimensional poverty rose from 42% to 82% in the period 2019-21 (219);¹⁵ and the official unemployment rate had risen to around 30% by January 2022 (220). Recent analyses indicate that effects of the crisis among displaced populations have been more

¹³ Figures come from the Vulnerability Assessment for Syrian Refugees (VaSyR), a study carried out by UN Agencies in partnership with the Lebanese government annually and drawing on a representative sample of refugee households registered with UNHCR living across Lebanon. The poverty line assessment is based around a metric called the Survival Minimum Expenditure Basket (SMEB) – defined as “the absolute minimum amount required to cover lifesaving needs”. This is determined based on the volume and type of purchases carried out by Syrian refugee households.

¹⁴ The disjuncture between stated (official) and “black market” exchange rates in Lebanon is considerable, partly because of the artificially low level at which the official value of the Lebanese currency had been pegged relative to the US\$ since 1997. Due to declining availability of goods on the open market many Lebanese residents are obliged to pay at grossly inflated, black market rates. A mooted move to re-peg the currency in November 2022 did not come to fruition.

¹⁵ This estimation uses a multi-dimensional poverty index considering 20 indicators across 6 dimensions, spanning education, health, public utilities, housing, assets and property, and employment and income.

pronounced than among host communities (214). As later chapters will show, the combined effects of these changes on household income, and on funding and resources available for essential health services, has been considerable.

3.1.2.3 COVID-19

In common with many countries worldwide, Lebanon has experienced a series of COVID-19 waves since the first cases globally were reported in December 2019. As of 25th November 2022, there had been around 1.2 million confirmed cases of infection nationwide since the first ones were identified in February 2020, and some 10,700 deaths occurring principally across two large waves (in autumn/winter 2020-21 and winter 2021-22) (221). Imposition of restrictions linked to COVID-19 has been intensive for large periods of Lebanon's COVID-19 response and has included regular use of lockdowns to limit domestic movements, as well as international travel restrictions. These measures and other factors linked to the spread of COVID-19 have contributed to large declines in uptake of essential health services, including childhood vaccination (222).

3.1.2.4 The Beirut blast

On 4th August 2020, an explosion in Beirut caused by improperly stored ammonium nitrate in the city's port killed some 190 people, seriously injured a further 6,000 and left around 300,000 residents of the capital homeless (206). Although structural effects were limited to greater Beirut, the impact was nevertheless substantial. Three major hospitals in Beirut were put out of operation due to blast damage, and around 20 primary healthcare centres – serving some 160,000 patients – were either destroyed or damaged. The national vaccine storage warehouse in the port was also destroyed. A large humanitarian relief operation was mounted in response, in parallel to the response already in place to cater for Syrian refugees (206). Further details of this – where relevant to the thesis – are presented in the empirical analysis chapters below (Chapters 5 and 6).

3.2 The health sector in Lebanon

The health sector in Lebanon is fragmented. There is large and powerful private sector, and international actors also have a significant role in health sector financing and service delivery. Relationships between “mainstream” health services and humanitarian response actors are complex (223–227). This has not always been the case. The Civil War of 1975-1990 had a powerful re-shaping effect on relations between public providers on one hand, and private and not-for-profit actors and humanitarian response organisations on the other, with the latter taking on an increasing role in regular service provision (223–227). The Civil War also undermined the central, norm-setting function of the Ministry of Public Health (MoPH), and its role in preventive services. Instead, perhaps as much as 80% of the MoPH's budget is now

dedicated to payments for curative services (224). Indeed, the shape of the health sector in Lebanon is strongly skewed towards curative care (228–230). Services are also for the most part concentrated in urban centres and particularly Beirut, with long-standing access barriers to primary and particularly specialist care for rural populations (206).

Some accounts have emphasised the resilience of the health system in the face of large-scale population movements since the start of the Syria crisis (54). Many others, however, have highlighted the growing challenges of meeting rapidly increasing demand for health services, with progressively intensifying resource, policymaking and implementation constraints (203,231–233). Response modes to the shocks described above have varied over time and are picked up in more detail in the results chapters later in the thesis. International actors (donors, technical agencies and non-governmental organisations or NGOs) have played an important role in supporting health service delivery in Lebanon especially since the Civil War during which capacity both centrally in the MoPH and peripherally at the level of publicly supported health facilities was progressively hollowed out (224,225,228,229). Since the beginning of the Syria Crisis, however, the international presence has grown markedly and is coordinated through at least three frameworks: the Lebanon Crisis Response Plan (LCRP) (addressing refugee arrivals from Syria), the Emergency Response Plan (ERP) for Lebanon (addressing needs among vulnerable Lebanese following the economic crisis and Beirut blast), and a regional response plan providing support to refugees displaced from Syria across the Middle East and North Africa (3RP). The LCRP and ERP each contain dedicated health components including support to primary care services, working with the Ministry of Public Health (MoPH). Coordination mechanisms for each have until recently been distinct, but management of the health sector response is now coordinated through a single working group.

3.3 Vaccination delivery in Lebanon

3.3.1 Governance and delivery arrangements

Mirroring the broader provider landscape, vaccination delivery in Lebanon is fragmented (Figure 9). Until recently, private clinics and dispensaries have exercised the dominant role in vaccination delivery, providing up to 60-65% of doses administered nationally according to some stakeholder estimates¹⁶, although the exact figure is uncertain. Other prominent delivery modes include through the charitable sector, the MoPH's primary healthcare centre (PHC) network, and a network of Social Development Centres (SDCs) operated by the Ministry of Social Affairs (MoSA). Private providers are independent. Many dispensaries and all PHCs

¹⁶ Figures drawn from stakeholder interviews for this thesis.

operate through partnership arrangements with local and/or international non-governmental organisations (NGOs) that provide financial, technical and other forms of support.

Available access points for vaccination vary by population. Host communities can access vaccination via any of the routes described above although historically the preference for private providers has been strong (see Chapters 5 and 6). A key, and early policy response to the arrival of Syrian refugees in Lebanon was to make routine immunisation available to new arrivals through MoPH-supported PHCs free of charge (234). By historical convention, Palestinian refugees are served separately by a network of clinics operated through the UN Relief and Works Agency (UNRWA). Refugees of Palestinian origin who arrived in Lebanon from Syria (for example, from the large camp in Yarmouk) were eligible for UNRWA services including vaccination, even though the Syria conflict was the trigger for their displacement. Other access points include a small but emergent informal provider sector serving refugees,¹⁷ although the share of vaccinations delivered by this route as a proportion of the national total is thought to be small (235,236).

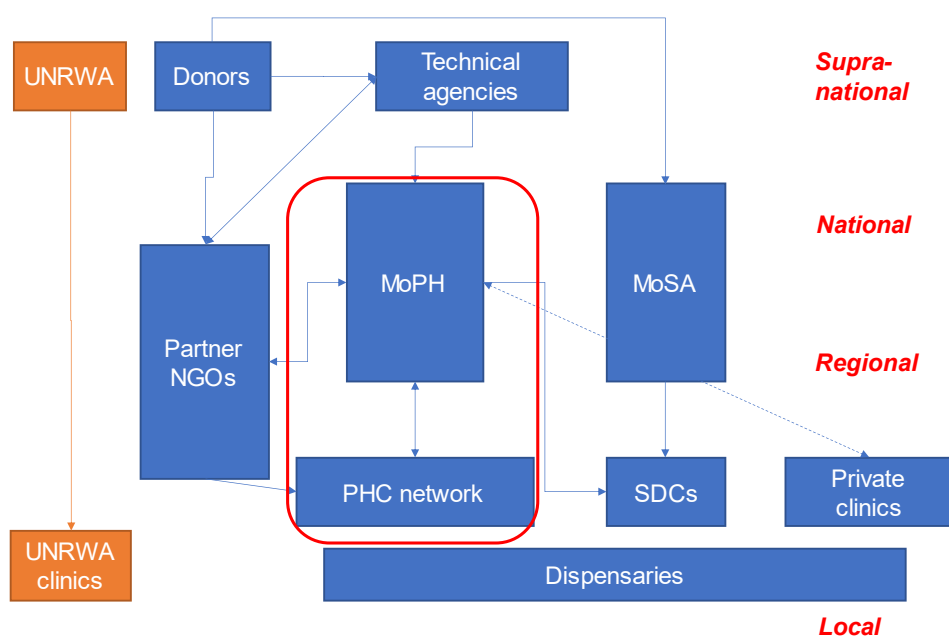


Figure 9. Simple schematic representation of key responsible organisations and service delivery pathways for vaccination from supra-national down to local level in Lebanon.

Ministry officials and partner NGOs occupy important bridging positions in this structure between national and regional, and national and local levels respectively. UNRWA services are represented separately as they fall outside the direct purview of the MoPH in Lebanon from a governance perspective. The focus area for the thesis is highlighted in the red box in the middle of the diagram [Abbreviations: MoPH = Ministry of Public Health; MoSA

¹⁷ This network emerged principally to meet demand for services among displaced Syrians in rural areas and those adjacent to the Syrian border, where access to health services has historically been poor.

= Ministry of Social Affairs; PHC = Primary Healthcare Centre; SDC = Social Development Centre; UNRWA = UN Relief and Works Agency]. Source: author-generated figure.

Costs across these access points vary. Vaccination delivery through the PHC network is heavily subsidised so that patients theoretically cover only administration fees (typically ranging from US\$5-10 per consultation for Lebanese residents, \$2-5 for Syrian refugees)¹⁸. Private provider fees for vaccination range from US\$20-100 per consultation excluding vaccine product costs, the addition of which may take total costs to in excess of \$200 depending on the antigen being administered.¹⁹ However, cost estimation is complicated by the skewing effect of rampant inflation in Lebanon since autumn 2019.

From a governance and financing perspective, at the outset of the study all PHCs were required to report vaccination delivery data to the MoPH, which regulated activities in the network. However, private clinics did not do so. Only a subset of dispensaries reported dose usage data to the MoPH. Financing and product procurement for the Expanded Program on Immunisation (EPI) overall lay with the MoPH with support from UNICEF (since 2013). UNICEF also provided technical input to programme oversight (234). Private sector providers operated independently of this system, procuring through separate mechanisms and delivering both routine and off-schedule vaccinations. A central theme in stakeholder discussions during the scoping phase of this research project was the parlous state of financing for vaccination through the national EPI programme in Lebanon. As a middle-income country Lebanon had no recourse to funding support from Gavi, the vaccine alliance, and the MoPH was (and continues to be) heavily dependent on donor and domestic funding sources to keep the national vaccination programme running.

3.3.2 Vaccination coverage across populations: what do we know?

Detailed longitudinal analyses from Lebanon are in short supply and cross-sectional assessments of vaccination coverage among displaced populations are particularly vulnerable to recall bias and other data shortcomings (55). However, time series data on administrative coverage for key antigens in Lebanon show large declines in national coverage broadly coinciding with the shocks described above (Figure 10), with only weak recovery following the lifting of COVID-19 restrictions (206).

Analyses published since 2011 have also shown substantial variation nationwide in the extent of coverage, and significant differences in the effectiveness of delivery (including timeliness) across populations (237–239). Coverage rates for a series of routine childhood immunisations

¹⁸ Exploratory stakeholder discussions 2 and 3.

¹⁹ These cost estimates reflect benchmarks described by stakeholders in the scoping study; they do not take into account price inflation as the economic crisis intensified.

have been shown in a number of studies to be lower for Syrian children than host community counterparts. Syrian children may also be less likely to receive vaccinations in accordance with the timeline set out in the Lebanese national immunisation schedule (237,240).

Variations in routine immunisation coverage between Syrian and host community populations have raised concerns about communicable disease outbreak risks, especially in light of documented outbreaks of high-consequence VPDs including polio in neighbouring Syria (241,242). However, outbreaks documented inside Lebanon since 2012 (most notably, a large-scale measles outbreak in 2018-19) appear to have been driven by geographically focused pockets of sub-optimal coverage including among host communities in a context in which affordability of, and access to, basic care has been highly variable (243).

Early analyses of effects on vaccination uptake since the beginning of the COVID-19 pandemic have shown very large reductions in uptake during the first lockdown in 2020 (222), and although data from publicly-supported primary care providers indicates a degree of recovery since, this has been sluggish. To date, there has been no wider analysis of effects on vaccination uptake linked to worsening socioeconomic conditions in Lebanon.

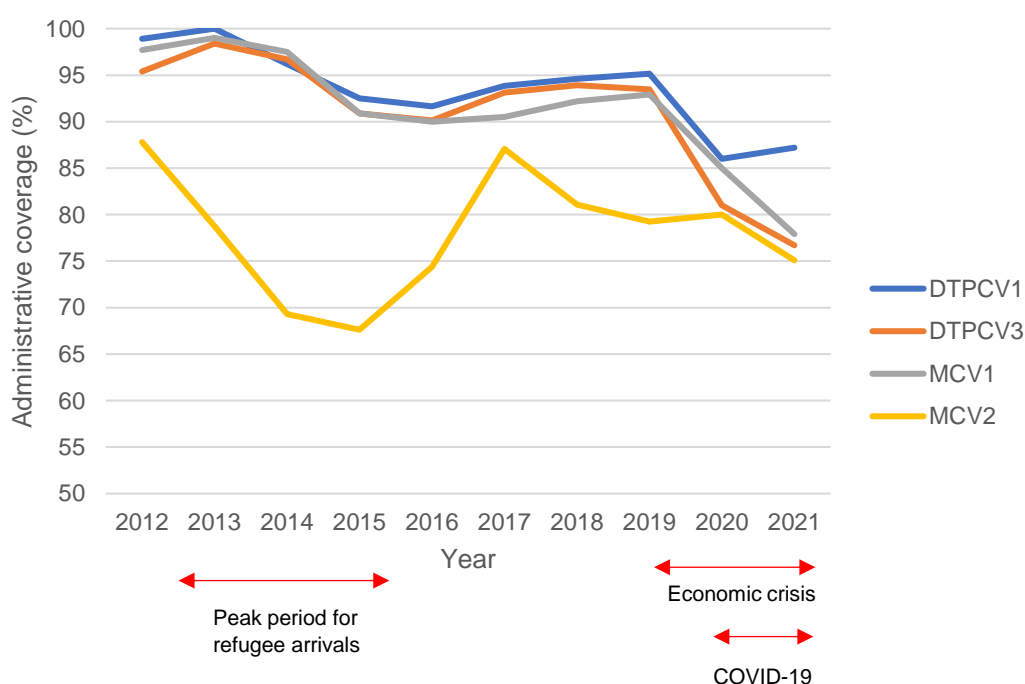


Figure 10. Administrative vaccination coverage rates (national) for selected antigens in Lebanon in the period 2010-20.

Approximate timing of the primary shock of interest (refugee arrivals) in this study are indicated in red lines near the base of the diagram, with subsequent shocks indicated to the right. Abbreviations: DTPCV1 = first dose diphtheria, tetanus and pertussis vaccination; DTPCV3 = third dose; MCV1 = first dose measles vaccination; MCV2 = second dose measles vaccination. Source: WHO Immunisation Statistics (244)

3.4 Chapter summary

This chapter has outlined key features of the project context. It has focused in particular on an overview of the vaccination delivery landscape in Lebanon, and dimensions of the compound crisis that forms the “exposure” of interest in the analyses that follow. Detailed analysis of the intersection(s) of these shocks as they have related to vaccination delivery will form an important focus of the remainder of the thesis. The next chapter, Chapter 4, provides an outline of methods used in this research project, before empirical results are summarised in Chapters 5-7.

CHAPTER 4: Methods

This chapter describes the research methods applied in this thesis, provides overarching rationales for each of the studies, and details the theoretical justifications for why specific methodological approaches were chosen. The chapter opens with a description of a preliminary analytic step performed at the outset of the research project: the scoping study. This was used to help define the problem for investigation (section 4.1). Findings from the scoping study provide the background to the project outline (4.2), which sets out the research design and key aspects including the system boundary definition for the work. Sections 4.3-4.5 go on to describe the methods applied in each of the studies comprising the thesis, focusing principally on the rationale for method selection in each case. Methods for each study are described in much greater detail in the relevant papers in Chapters 5-7.

4.1 Preliminary step: scoping study

The scoping study used a mixed methods approach, triangulating data from multiple sources in three steps, to inform the problem statement given in section 1.5. It comprised:

- A mixed-methods, subject-area analysis addressing determinants of vaccine demand and supply in humanitarian settings. This drew on literature analysis and exploratory discussions with a selection of global vaccination delivery and financing stakeholders;
- Two mixed-methods, country case studies exploring vaccination delivery in Lebanon (the focus country for this thesis) and Uganda (a second case study for which data collection and analysis is ongoing, and which is therefore not included in this thesis); and finally
- A synthesis step bringing together findings from the various elements of the scoping study to produce the problem statement set out in section 1.5.

Further details of the methods employed in each step of the scoping study, and the results of this analysis, can be found in **Appendix 2**. Summary results of the scoping study, and their implications in terms of the design of the research project, are reported in section 4.2 below.

4.2 Outline of the project

This was a mixed methods research project built around an in-depth country case study on routine childhood vaccination delivery in Lebanon. The work brought together a range of methodological approaches to interrogate resilience through the prism of routine vaccination

delivery. The empirical studies comprising the research project contributed to specific objectives as outlined in Figure 11 below.

The thesis comprises three, empirical studies:

- Study 1: a qualitative, system dynamics modelling analysis. This study focused on causal mapping of shock effects and system responses in the vaccination delivery system in Lebanon, to address the second and third research objectives. Findings from this study are reported in papers 2 and 3 in Chapter 5.
- Study 2: a qualitative, thematic analysis. This study empirically evaluated the validity of a resilience governance framework in explaining system responses to shocks in Lebanon, to address the fourth research objective. Findings from this study are reported in paper 4 in Chapter 6.
- Study 3: a systematic review to identify resilience-promoting interventions to support childhood vaccination delivery in humanitarian settings. Findings from the systematic review are reported in paper 5 in Chapter 7 and address the fifth and final research objective.

Studies 1 and 2 used some common data sources, as later sections in this chapter will explain. Figure 11 below maps these three studies, and the preliminary theoretic work in Chapter 2, to the study objectives given in Chapter 1:

Research objective						
Study	Paper	1. Improve conceptual understanding of shocks	2. Explore the effects of compound shocks	3. Identify system pathways and attributes contributing to system resilience	4. Assess the role of governance and legitimacy in contributing to system resilience	5. Identify evidence-based interventions to strengthen resilience to shocks
Resilience theory narrative review	1					
Study 1: causal loop diagram development	2					
	3					
Study 2: qualitative analysis of governance, legitimacy and resilience in vaccination delivery	4					
Study 3: systematic review of resilience-promoting interventions	5					

Figure 11. Mapping of studies within the thesis, and the broad thesis objectives to which each sub-study relates.

4.2.1 Design of the research project

A case study design was chosen for the research project because this approach can be particularly instructive in instances where the boundary between a phenomenon of interest, and the context in which it occurs, is blurred (245). The country case study – details of which were given in Chapter 3 – was selected as an extreme example of what Yin might describe as an “exemplifying” case: one where system responses to a range of overlapping shocks can be explored (246). Importantly, Lebanon was selected because it had experienced large-scale population movements from Syria recently and had adopted a policy of refugee integration regarding access to essential primary care services such as vaccination. This meant that refugees and host communities could now receive these services through common access points. Further details of the rationale for the case selection are given in **Appendix 2**.

4.2.2 Selection of, and justification for, chosen outcome measures

Although the findings reported in this thesis are primarily qualitative, two quantitative, primary outcome measures were chosen for the research project: the percentage population coverage for Diphtheria, Tetanus and Pertussis (DTP) vaccination and Measles-containing vaccination (MCV). Quantitative outcome measures were selected to give focus to interview discussions around vaccination delivery in Studies 1 and 2, and to inform the selection of outcomes for the systematic review work in Study 3. The choice of these two antigens was also deliberate. DTP is recommended by WHO for inclusion in EPI schedules worldwide. Population uptake of the third dose of this vaccination (DTP3) is a routinely used marker of the effectiveness of vaccination delivery worldwide (49). Measles vaccination, on the other hand, is both recommended by WHO for use in national schedules under routine conditions, and among the most widely recommended public health interventions in emergencies (247). The combined focus on these two vaccinations enabled assessment of capacity to both upscale *routine* vaccination delivery (both DTP and measles vaccination), and adaptation to newly emergent needs in the event of large-scale population movements (measles vaccination).

4.2.3 Time horizon for the research project

The time horizon for the research project was set at 20 years: 10 either side of the launch point for the work (2019). This time horizon was chosen partly with reference to potential future quantitative simulation modelling (which is in progress and is not reported in this thesis). It also enabled medium-term analysis of system responses to the various shocks Lebanon has experienced, to better accommodate their dynamic nature. Population displacements, for example, rarely occur at single time points. Instead, they tend to span a number of years. This was certainly the case in Lebanon, where arrivals were sustained over several years from 2012 onwards, but with continual cross border movement – both out of and back into Syria – throughout the study period.

4.2.4 Defining system boundaries


Determining the boundaries of a system (i.e., those factors to be classified as endogenous or exogenous to a problem of interest, and therefore excluded from formal modelling) is a key first step in any system dynamics project. Based on initial consultation with stakeholders during the scoping study (see **Appendix 2**), the system boundary for this study was set at national level. The boundary definition included structures concerned with vaccination delivery nationally. It also included sub-systems analysis to reflect dynamics relevant to vaccination delivery at regional and local (facility) level. However, the complexity of the service delivery landscape in Lebanon, and challenges of data availability for private providers, necessitated a primary focus on dynamics relevant to delivery through the publicly supported network of PHCs. The implications of this for interviewee sampling are set out in sections 4.3-4.5.

4.2.5 Identifying leverage points within systems

To help make sense of system vulnerabilities and potential points of intervention identified through empirical work, this thesis draws on a recognised framework from systems thinking. In her work, *Thinking in Systems*, Donella Meadows describes a series of “leverage points” with progressively increasing degrees of impact on key system outcomes (248). In Meadows’ typology, leverage points fall into four broad categories (the second column in Table 2):

- Events or patterns of behaviour: these typically describe changes to individual variables within the system. Interventions at this level are theoretically easiest to implement but have correspondingly low impact on system outcomes.
- Underlying system structures: these leverage points concern the relationship(s) between parts of a system – including time delays and feedback loops.
- Information flows and mechanisms of control within the system: these leverage points include the rules by which the system operates.
- Mental models or beliefs: these leverage points concern factors including the rules governing a systems’ behaviour, and perhaps even the paradigm under which it operates. Change at this level is hardest to achieve but potentially highest in impact.

Table 2 describes each of the 12 levers in more detail and identifies examples of interventions or practices operating at each level with respect to vaccination delivery. Importantly, interventions in the table are ordered in terms of both potential level of impact and of likely system resistance to change. Interventions near the top of the table are likely to have lower impact, and resistance to change is correspondingly low.

No	Type of lever	Specific leverage point	Definition	Examples (with reference to vaccination delivery)	Impact of change
12	Events or patterns of behaviour within the system	Constants or parameters within the system	Variables within the system that could be increased or decreased to support responses to shocks	Numbers of health workers able to administer, or the number of viable vaccine doses available to administer	LOW 
11	System structure(s) explaining events and patterns of behaviours	Buffers	Fixed points in the system that modulate the flow of material or information, and generally act to stabilise the system	The presence of a central vaccine storage facility with surplus stocks to enable unexpected surges in demand to be accommodated	
10		Stock-and-flow structures	This leverage point describes the overall structure of a system, or series of systems and how they intersect. The leverage point is in the proper design of the system in the first place – so change by this mechanism is very slow.	Population churn determining the number of children to be vaccinated within a system; the physical infrastructure at facility level to support vaccination delivery.	
9		The length of important time delays	Delays affecting the flow of information or material from one part of the system to another	The time taken to distribute vaccine doses from central supplies to facility level; the time taken for surveillance information from facilities to reach the centre to support decision-making	
8		The strength of balancing feedback loops	Balancing feedback loops often emerge in systems to correct specific behaviours.	Interventions designed to increase population awareness of the importance of vaccination, and to increase trust in service delivery, are likely to counteract the negative effects of hesitancy on vaccination uptake	
7		The strength of reinforcing loops	Reinforcing loops often emerge in systems to amplify specific behaviours.	Interventions designed to increase population level trust in service delivery are likely to have a reinforcing effect on clinic attendance	


6	Information and controls systems influencing how the system works	The structure of information flows	Information flows determine who has access to information and of what form.	Mechanisms governing who has access to information on vaccination uptake, at what level of granularity and for what purpose.	
5		System rules	These describe the incentives, constraints and other rules governing the behaviour of actors within the system.	Health financing interventions such as pay for performance may act at this level by changing incentive structures for service providers.	
4		Self-organisation	Systems can add, change or evolve their structure, based on learning.	The creation of an entirely new service pathway for the delivery of vaccination in response to an environmental change or change in patterns of service demand.	
3	Mental models (values, beliefs and assumptions) that govern how the system works	System goals	These describe the purpose or function of the system – change at this level can drive fundamental system re-organisation.	Goal re-orientation from for-profit service delivery to delivery with the goal of maximising population-level protection from vaccine preventable diseases.	
2		The paradigm out of which the system arises	Paradigms describe the tacit “world view” that governs how a system operates – because all those within it accept it as read. True paradigm changes in social systems are rare, but their potential impact is enormous.	Polio programming worldwide has been structured for some years around an eradication paradigm. The movement of disease prevention and control activities between control vs elimination vs eradication would represent potential paradigm shifts in approach.	
1		Transcending paradigms	The highest degree of leverage is achieved by those who realise that no one paradigm is “true” and are able to act flexibly without reference to a specific paradigm.	Real-world examples of extra-paradigmatic approaches or interventions in health are not readily identifiable.	
					HIGH

Table 2. System “leverage points” as defined by Donella Meadows.

The column at right indicates the degree of impact that could be expected from each intervention, from low (for interventions addressing specific constants or parameters within the system) to high (for interventions that change the paradigm by which a system operates). The leverage points are drawn from Meadows’ book, *Thinking in Systems* (2008) (248).

By contrast, interventions towards the bottom of the table may be much more strongly resisted but the potential impact is high. Importantly, while leverage points can be used to support positive change, they are frequently first identified when things go wrong. In this sense, leverage points help identify potential sources of system vulnerability, but can also (with appropriate supportive action) support resilience.

This thesis draws on Meadows' typology of system leverage points as a common thread to try to understand how and where potential interventions might act to improve coverage of childhood vaccinations over time in humanitarian settings. I return to it particularly in Chapter 5, but again briefly following each of the ensuing results chapters.

4.3 Study 1: Using system dynamics to explore shock effects and vaccination delivery system responses in Lebanon

4.3.1 Rationale for using a qualitative system dynamics approach

In Chapters 1 and 2, we saw that prevailing conceptual and methodological approaches to analysis of health systems, and of vaccination delivery systems more specifically, are limited in the extent to which they are capable of capturing dynamic behaviour. They are particularly limited in their capacity to identify feedbacks and interdependencies within systems that can determine responses to shocks. Per Sterman, systems thinking has important advantages over conventional analytic approaches in “replac[ing] a reductionist, narrow, short-run, static view of the world with a holistic, broad, long-term, dynamic view” (249). Sections 1.4.2 and 1.4.3 described in further detail the analytic advantages systems approaches, and system dynamics in particular, offer relative to others for the analysis of resilience.

The principal, qualitative means for elucidating causal links between variables in system dynamics is the Causal Loop Diagram (CLD). **Appendix 4** provides a general introduction to CLDs, their purpose and notation. CLDs enable a causal map to be developed based on stakeholder data. They visually map out key system variables, causal links between them and – where relevant – feedback loops or delays that may influence system behaviour over time. CLDs enable *inferences* regarding dynamic behaviour within systems to be made but cannot definitively *deduce* it. For this, simulation modelling is typically required (123).

The purpose of this first study was – through CLD generation – three-fold:

1. To describe each of the shocks in Lebanon, as delineated through their effects over time on childhood vaccination delivery at multiple levels (from national to facility level) and across populations (both refugee and host community);
2. To explore system responses to these shocks over time; and

3. To identify potential leverage points for intervention to strengthen system resilience over the long-term.

A final function of the study was to explore the practical application of system dynamics to exploring system resilience in a humanitarian setting. While a handful of studies have applied causal mapping to the analysis of resilience in essential health services in these settings previously, these have all had a general health service focus (111,250). A novel aspect of this study was the focus on vaccination delivery specifically.

In addition, prior work in humanitarian settings has primarily used group model building (GMB) as the chosen methodological approach (see **Appendix 1**) (110,111,251). GMB is an analytical approach in which facilitated group discussion conforming to a pre-defined set of structural principles is used to develop a CLD by consensus. While this approach has important strengths, it is resource intensive and depends on being able to convene key stakeholders in a single venue for a sustained period (usually 1-2 days). GMB was not used in this research project for two reasons. Firstly, there were practical concerns regarding the ability to convene a suitable range of stakeholders in one venue at one time, especially given the constraints imposed by COVID-19. Secondly, there were concerns regarding the management of unequal power relations between participants working at different levels in the system in Lebanon, some of whom were contractually accountable to one another. As Chapter 3 has shown, the health sector in Lebanon is highly fragmented with large power inequalities between key players in the health sector. Instead, this study applied purposive text analysis to data gathered through stakeholder interviews in Lebanon, as 'proof of concept' for this approach in a humanitarian setting.

4.3.2 Data collection and management

Interviewees were sampled purposively from organisations with a stake in routine vaccination delivery in Lebanon. They included representatives from government, from donors and agencies supporting the LCRP, from non-governmental organisations, from the private sector, and finally from service managers and practitioners involved in front-line primary care service delivery. Interviewees were grouped into three categories, as follows:

- Category 1: national level stakeholders, including representatives from the MoPH, representatives of donor organisations, and domain leads from international agencies;
- Category 2: regional-level and cross-level stakeholders, including regional representatives from the MoPH, regional health sector coordinators under the LCRP, and medical coordinators or equivalent from implementing partners supporting service delivery; and

- Category 3: facility-level stakeholders, spanning PHC representatives in leadership positions (PHC managers or medical directors) and those in service delivery roles (e.g., nurses tasked with vaccination delivery)

Facility-level data collection was designed to better understand dynamics affecting service delivery in two governorates in Lebanon: Beirut and Akkar. Participant recruitment in category 3 was therefore focused on these localities, making use of the national PHC contact list held by the MoPH. These locations were chosen to reflect the breadth of service delivery challenges across the country. Beirut incorporates the country's capital, the focal point for logistics and supply chains relevant to vaccination delivery, and has been the major hub for humanitarian actors, NGOs and others supporting the humanitarian response to the Syria crisis in Lebanon for many years. It is also the location in which many of the country's private paediatricians are based. Akkar is a border governorate in the North of the country which hosts a large refugee population and where a significant proportion of the host community population are socio-economically deprived. It has also historically suffered from lower investment in public services than in other areas of Lebanon and has been among the areas worst affected by the economic crisis since late 2019.

Interviews were carried out using a semi-structured topic guide (given, alongside other research tools, in **Appendix 5**). This gathered information on [i] interviewees' professional roles and the activities of the organisations for which they worked, [ii] their understanding of how the vaccination system in Lebanon operated, and [iii] their experiences of change following each of the shocks. The topic guide was designed specifically to probe for causal information to facilitate later CLD development.

A total of n=38 interviews were carried out in two waves (February-March 2020, and then July 2021-February 2022) (see Table 3). Of these, n=8 were carried out in-person in Beirut, and the remainder remotely via Zoom calls owing to COVID-19 disruptions. Interviews were recorded and transcribed into MS Word. The majority of interviews were performed in English. However, all facility-level interviews bar one (n=6) were performed in Arabic with support from a research assistant to the project. For these interviews, I transcribed audio recordings, translated transcripts from Arabic into English, and then performed the analysis.

4.3.3 Generation of the Causal Loop Diagram

The CLD was generated in 3 steps. First, a CLD was developed for each individual interviewee to represent their understanding of the effects of shocks linked to the compound crisis in Lebanon, on routine vaccination delivery. Second, individual CLDs were combined to form aggregate CLDs. Finally, a series of validation checks were performed. Each of these steps is described in further detail below; additional details are also provided in Chapter 5.

Table 3. Breakdown of interviews conducted, by stakeholder group and timing – all interviews.

The table also summarises the distribution of interview transcripts across the analysis and validation sets for CLD development.

Stakeholder group	Sub-category	Wave 1 (Feb-Mar 2020)	Wave 2 (Jul 2021-Jan 2022)	Analysis set	Validation set
National	Government	2	1	16	2
	Donors	0	4		
	Agencies	5	5		
	Private sector	0	1		
Regional bodies and implementing partner organisations		1	12	11	2
Local – facility level	Akkar	0	5	6	1
	Beirut	0	2		
Wave total		8	30		
Overall total		38		33	5

4.3.3.1 Step 1: generation of individual CLDs

Interview transcripts were split into two sets: a core analysis set (from which the CLDs were derived) and a validation set (set aside for use in step 3 – as outlined below) (Figure 12). From the core analysis set, individual interview transcripts were coded in MS Word using purposive text analysis. This followed an approach previously described by Kim *et al* and Tomoia-Cotisel *et al* (252,253). The focus of purposive text analysis, in contrast to more conventional thematic analysis approaches, is on language that is explicitly *causal*.

As a first step, text segments in interview transcripts were coded if they described events, processes or items (e.g., stocks of a particular good) relevant to vaccination delivery system responses to the shocks of interest. We also considered text segments that described resilience attributes (e.g., collateral service pathways) that might explain these responses. Finally, text segments were coded if they addressed relevant local (i.e., facility-level), meso- (i.e. regional) or macro-level (i.e. national) system behaviours.

Coded segments were then transferred into a separate MS Excel template for Rigorously Interpreted Quotations (RIQs) (see **Appendix 6** for a sample template and an example quote interpretation). RIQs enable the deconstruction of text segments to identify relevant variables and causal language that link one or more variables together. Finally, they allow for the directionality of these relationships to be determined – in other words, whether the relationship was quantitatively positive or negative – so that this can be graphically represented (253). Variables and relationships identified in this way were then visually mapped in Vensim®, a

proprietary, system dynamics modelling software tool (254). This process was repeated for each interview transcript in the analysis set, to develop a total of $n=33$ individual CLDs.

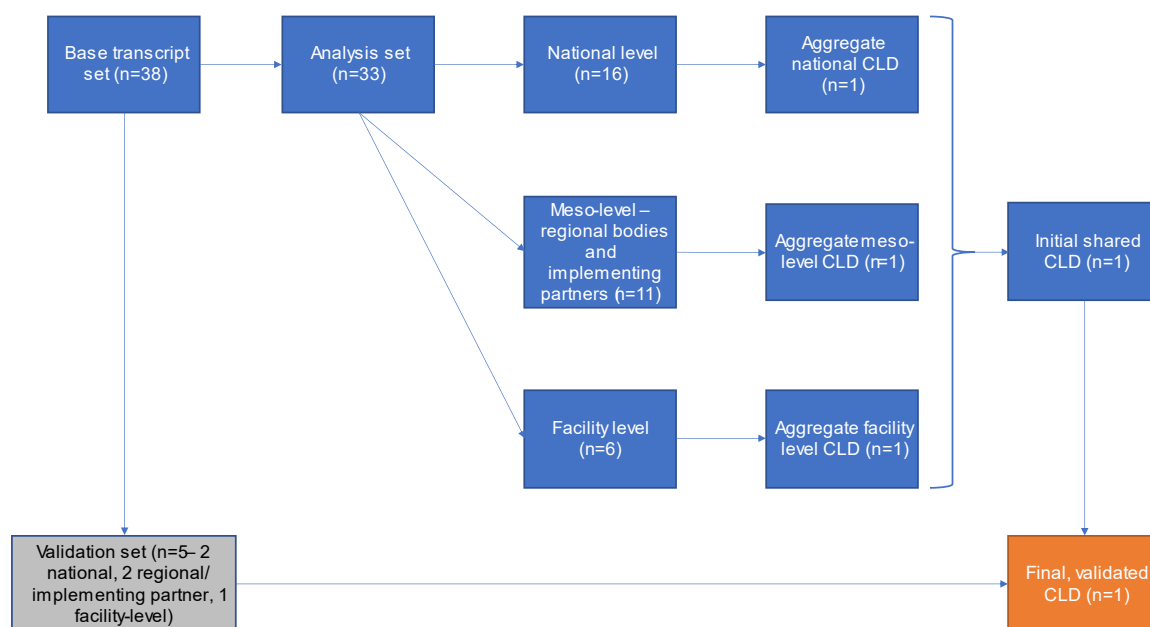


Figure 12. Schematic representation of the process for generating the initial, shared CLD from the analysis set. A total of $n=5$ interviews were set aside for use as part of the validation set, as outlined below.

4.3.3.2 Step 2: combining and editing CLDs

To combine CLDs, individual CLDs were first grouped according to the stakeholder category from which they originated, and then ordered within these groups in terms of their complexity. The level of complexity in a CLD was determined based on the number of the following each contained, in order: [i] feedback loops; [ii] delays; [iii] causal links; and finally [iv] variables. The most complex CLD within each stakeholder group was chosen as the base diagram for combination for each stakeholder group, because it contained the richest information. This was termed the “anchor” CLD for each group, with which individual CLDs were combined, in order of their complexity.

Before any combination was attempted, however, individual CLDs were first subjected to mild pruning. In this process, extraneous links were removed to focus down on core variables and links between them. Only delays (any instance in which there was a material or information delay between two variables in a link) and feedbacks (any instance where there was a clear circular link or set of links between variables, whether positive or negative) were retained in this pruning process, following an approach set out by Yearworth (255).

Within each group, the anchor CLD was then combined with the next most complex CLD. The process of combination was to compare the two CLDs with one another, and to try to identify

variables and loops that were contained in the second CLD but missing from the anchor. These were then added to the anchor. Where two CLDs described the same behaviour but in different ways, the more complex representation was retained, on the assumption that this was likely to give a fuller understanding of dynamics in that sector of the diagram. This process was repeated within and then across stakeholder groups to yield an aggregate diagram. Saturation – assessed in terms of the number of additional variables, links, delays and feedback loops added to the anchor with each additional individual CLD – was monitored using saturation curves (reported in **Appendix 7**).

4.3.4 Evaluating the internal validity of the Causal Loop Diagram

To evaluate the internal validity of the aggregated CLD from Step 2, interview transcripts from the validation set were reviewed, coded and analysed in the RIQ template to determine whether this material confirmed the structure in the CLD, or whether further changes were needed. A total of n=5 interview transcripts were retained in the validation set to enable this analysis to be performed.

4.4 Study 2: qualitative exploration of governance, legitimacy and resilience in vaccination delivery

In study 2, I used a subset of the interviews gathered to support CLD development to look specifically at questions concerning system governance and legitimacy, and the relationships of these to resilience in vaccination delivery over time. The purpose of this study was two-fold. First, it aimed to provide deeper context for findings emerging from the system dynamics component in study 1, by grounding these in an analysis of the evolving governance context in which childhood vaccination delivery has occurred in Lebanon since 2012. A second goal was to empirically test a widely cited conceptual framework on governance for resilience from Blanchet *et al* that focuses on supply-side factors (10).

4.4.1 Theoretical approach

In developing our conceptual approach, we drew on a WHO definition of health system governance, and the study by Blanchet *et al* (10). Per WHO, “leadership and governance involves ensuring strategic policy frameworks exist and are combined with effective oversight, coalition-building, regulation, attention to system-design and accountability” (256). The resilience governance framework sets out three system capacities contributing to resilience – namely absorptive, adaptive and transformative capacity. These are in turn underpinned by four governance capacities:

- The ability to integrate multiple types of information from multiple sources to develop meaningful *knowledge* about system behaviour;
- An ability to manage *uncertainty*;
- An ability to engage with multiple actors across system scales i.e. *interdependence*; and finally
- The institutional *legitimacy* to norm-set and ensure that those norms are observed (10).

In our analysis, we make no explicit, normative judgements about resilience and its contributory factors. Our focus is instead on the overall health outcome of routine vaccination coverage (i.e., durability in population-level coverage for DTP3, MCV1 and MCV2 vaccines) and aspects of system governance that may promote or undermine the achievement of that aim over time, in the face of compound crisis.

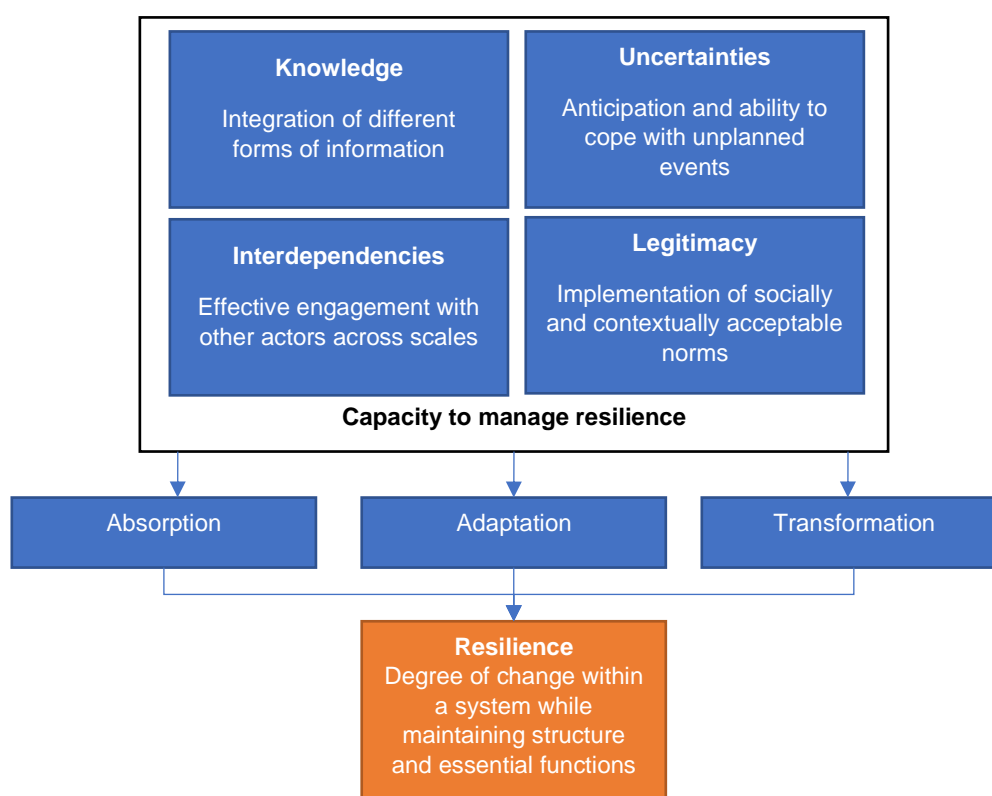


Figure 13. The dimensions of resilience governance.

Each of the four dimensions (knowledge, management of uncertainty, interdependence and legitimacy) contribute to overall capacity to manage resilience, which in turn dictates the extent to which a system is able to absorb a shock or adapt or even transform in response to it. Figure adapted from figure 2 in Blanchet et al (10): the original is licensed under CC BY 4.0, which permits unrestricted use, distribution, and reproduction in any medium provided the original work is properly cited – as outlined here:

<https://creativecommons.org/licenses/by/4.0/legalcode>.

4.4.2 Data collection and management

We drew on three sources of data to explore governance dynamics influencing resilience in routine vaccination delivery: (i) key informant interviews; (ii) meeting minutes; and (iii) strategy and operational documents. These sources were used to help triangulate findings, and to add further data particularly covering early phases of the Syria Crisis response for which interviewee recall might not be as strong.

The interviews were drawn from the same set used in study 1 but excluding respondents in category 3 (see section 4.3.2). Data were derived from a total of 30 interviews with 27 stakeholders working at national or regional level in Lebanon, including government officials, representatives from donors and technical agencies, and representatives from NGOs. Facility level respondents were excluded because the focus of study 2 was on meso- and macro-level governance structures (regional, national, and supranational), and because the focus of interview questions for facility-level respondents was primarily oriented towards service delivery.

Table 4. Breakdown of interviews conducted, by stakeholder group and timing – study 2.

Stakeholder group	Sub-category	Wave 1 (Feb-Mar 2020)	Wave 2 (Jul 2021-Jan 2022)	Full analysis set
National	Government	2	1	17
	Donors	0	4	
	Agencies	5	4	
	Private sector	0	1	
Regional	Government	0	1	3
	Agencies	0	2	
Implementing partner organisations (spanning national, regional and local)		1	9	10
Wave total		8	22	
Overall total		30		30

We also drew on 28 sets of publicly available meeting minutes from the national health sector working group (HSWG) for the response to Syrian refugee arrivals, which were gathered from the UNHCR operational data portal for the Syria Crisis response in Lebanon (207). These meeting minutes spanned HSWG meetings for the period from November 2013-December 2021.

Finally, we compiled strategy and operational documents including (i) MoPH strategies relating to health in general, and EPI vaccination in particular, for the period 2006-21; (ii) annual reports from the PHC network in Lebanon, published by the MoPH; and (iii) agency

contingency planning and LCRP operational documents relating to the refugee response, and then from 2020 onwards, relating to the ERP for Lebanon. Documents predating the Syria Crisis Response were included to help understand the extent of preparedness and planning for shocks. Relevant sections of documents published in Arabic were translated into English prior to analysis.

Data in all three of the categories described above were uploaded into NVivo 12 for analysis. All material was analysed in a single run in February 2022.

4.4.3 Analytical approach

Data were analysed using the framework approach (257,258). This pragmatic method combines inductive and deductive coding approaches and was chosen because of the existence of an established conceptual framework after Blanchet *et al* (10) on which we could build. Framework analysis involves five discrete steps:

1. Familiarisation with the data, in which an inductive approach is taken to identifying important themes from a subset of data;
2. Identification of a thematic framework – which typically combines themes from the familiarisation stage, with *a priori* themes drawn from prior work or the wider literature;
3. Indexing, in which material from remaining primary data are indexed according to the working framework;
4. Charting, in which material is organised by case or theme; and finally
5. A synthetic “interpretation” step in which key themes and links between them are distilled.

Interviews, meeting minutes and strategy and implementation documents were analysed as distinct groups (i.e., by source type), and themes across each of these three source types were then compared to identify points of commonality and difference.

4.5 Study 3: realist-informed review of interventions to strengthen vaccination delivery

This study was a realist-informed systematic review of peer-reviewed and grey literature on system-level interventions to strengthen vaccination delivery in settings of protracted humanitarian crisis. The aim of the review was to investigate what is known about the effectiveness of interventions to strengthen vaccination coverage in countries experiencing humanitarian crises, when, where and for whom (considering host communities, refugees and internally displaced populations). Our specific focus was on interventions, including promising early-stage interventions with emerging but limited evidence, to bolster system level resilience

to maintain vaccination coverage. Finally, we aimed to capture data on how these interventions operate at system-level, with a view to tailoring them to local implementation. To do so, we developed a review approach that was systematic and realist-informed, to ensure that material on intervention mechanisms was gathered alongside more conventional evidence on effectiveness.

4.5.1 Rationale for applying a realist-informed approach

Our approach drew on an emerging body of realist review work focusing not just on identifying which interventions work, but also explaining why they work, and for whom (259,260). We applied this approach for several reasons. Firstly, the diversity of humanitarian settings makes proper attention to contextual factors essential in understanding the likely success of different interventions and their combinations. Secondly, the overarching focus of this thesis required a fuller understanding of the likely effects of interventions on system behaviours (at multiple levels) over time rather than discrete effects on single outcomes. While realist reviews classically begin with a working programme theory that describes how the focus intervention is thought to work which is then amended in light of literature findings, developing a unitary programme theory was neither feasible nor desirable given the diversity of interventions considered here. Instead, our focus was on describing the putative mechanisms by which included interventions worked, in line with realist-informed systematic reviews published elsewhere (261–263).

The review was performed in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, and the protocol for the review was pre-registered with PROSPERO (CRD42021273124). We considered evidence on vaccination delivery interventions for populations in LMICs affected by protracted humanitarian crises (see Chapter 7 for details of the definition applied) with a particular focus on children aged 0-5. We also incorporated evidence on older displaced children, teenagers and adults in consideration of, for example, catch-up programmes.

4.5.2 Methodological approach

Full details of the methodological approach for the review are given in Chapter 7.

4.6 Ethics

Ethical approval for the research project was secured in the UK from the London School of Hygiene and Tropical Medicine (ref no 17461) and in Lebanon from the American University of Beirut (ref no SBS-2019-0376). Further details for these approvals are given in **Appendix 8**. Informed consent to participate was secured from all interviewees, using the materials in

Appendix 5. All data gathered during the research project were stored on password-protected computers, and all recordings (or otherwise identifiable information) stored securely on LSHTM servers to which only I had access.

While broad ethical challenges to social science research in LMICs for researchers from high income settings are well-recognised, there are specific constraints that apply in humanitarian settings (264). These are contexts in which risks to researchers and the communities they research are often amplified. There can be enormous challenges in ensuring equitable participation from stakeholders, for security and access reasons but also because of power imbalances. For research that seeks to engage decision-makers, there are also important questions to address concerning proper use of time for individuals who are under significant professional pressure and likely working at personal risk (264). In conflict-affected countries in the Middle East, there has been growing concern at exploitative research practices that privilege the interests of researchers from high income settings (who often bring funding support with them) at the expense of local researchers and of the in-country stakeholders that they seek to engage (265). Lebanon has for some time been a popular context for those interested in researching societies and health systems in contexts of humanitarian crisis in general and large-scale population displacement in particular, and there is a risk of research fatigue (266).

Strategies used in this research project to try to address the concerns outlined above included the collaborative design of the work, incorporating stakeholder feedback in formulating the problem statement and research questions (as outlined in **Appendix 2**), as well as regular stakeholder engagement throughout the project. Findings reported in this thesis were drawn in large part from stakeholder interviews, and the CLDs presented reflect interviewees' own mental models of how the vaccination delivery system in Lebanon operated during the study period. In addition, data collection was performed in partnership with collaborators at the American University of Beirut, and importantly, with brokering and support from the Primary Healthcare Department at the MoPH in Beirut who kindly provided a letter of support for the study for circulation to prospective interviewees working at facility level.

Finally, close attention was paid to security for participants throughout the project. In person interviews were conducted in settings nominated by the interviewees (predominantly their own offices). Remote interviews were conducted using secure communications and recordings uploaded directly to the LSHTM server for further handling. All data presented in this thesis are anonymised.

4.7 Funding

The research reported in this thesis was funded by a Wellcome Trust Clinical Research Training Fellowship (reference number 215654/Z/19/Z).

4.8 Chapter summary

This chapter has set out the rationale for the project design, the selection of research methods applied, and then addressed both the rationale and methodological approaches for each of the four empirical papers presented in the remainder of thesis. Following chapters will set out results (presented in paper style), before a discussion of common themes, study strengths and limitations, and broader policy implications in Chapter 8.

CHAPTER 5: Exploring vaccination delivery system vulnerabilities and resilience to shocks using Causal Loop Diagrams

5.1 Introduction

This chapter incorporates two empirical papers using system dynamics to explore shock effects on the vaccination delivery system in Lebanon over time. The papers report findings from an aggregated, validated CLD developed using purposive text analysis of n=38 interview transcripts. Interviews were carried out with stakeholders working at various levels in the vaccination delivery system in Lebanon. These papers address objectives 1-3 for the thesis, namely:

1. Improve conceptual understanding of system shocks with respect to health systems;
2. Explore the effects of compounding shocks on the vaccination delivery system in Lebanon, and identify real or potential sources of vulnerability within the system;
3. Identify specific system pathways or system attributes that may explain how and why the vaccination delivery system in Lebanon responded in the way that it did when affected by each of the shocks addressed in this research project.

A principal, conceptual focus of these papers was on identifying how and where each of the shocks in Lebanon affected the vaccination delivery system, and on the range of responses – both intrinsic to the system, and purposefully introduced as interventions – that took place as a result. In doing so, I aimed to identify leverage points – in line with Meadows' framework set out in section 4.2.5 – that could inform resilience-building strategies for application in Lebanon. I return to this theme in section 5.6.

5.2 Research paper cover sheet – paper 2



London School of Hygiene & Tropical Medicine
Keppel Street, London WC1E 7HT

T: +44 (0)20 7299 4646

F: +44 (0)20 7299 4656

www.lshtm.ac.uk

RESEARCH PAPER COVER SHEET

Please note that a cover sheet must be completed for each research paper included within a thesis.

SECTION A – Student Details

Student ID Number	1806401	Title	Dr
First Name(s)	Sharif Adel		
Surname/Family Name	Ismail		
Thesis Title	Resilience to shocks in national vaccination delivery systems: from analysis of shock effects to resilience-strengthening intervention approaches in Lebanon		
Primary Supervisor	Professor Josephine Borghi		

If the Research Paper has previously been published please complete Section B, if not please move to Section C.

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?*	Choose an item.	Was the work subject to academic peer review?	Choose an item.

*If yes, please attach evidence of retention. If no, or if the work is being included in its published format, please attach evidence of permission from the copyright holder (publisher or other author) to include this work.

SECTION C – Prepared for publication, but not yet published

Where is the work intended to be published?	Social Science and Medicine
Please list the paper's authors in the intended authorship order:	Sharif A. Ismail, Andrada Tomoaia-Cotisel, Aya Noubani, Fouad M. Fouad, Robert Sakic Trogrlic, Sadie Bell, Karl Blanchet, Josephine Borghi

Stage of publication	Not yet 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. (Attach a further sheet if necessary)	I conceived the study; designed the study with methodological input from AT-C, JB and KB; collected the data with support in Lebanon from AN; performed the data analysis with methodological input from AT-C; drafted the full manuscript; revised the manuscript with supervisory input from JB, KB and SB, and incorporating revisions from all authors.
--	---

SECTION E

Student Signature	Sharif Ismail
Date	02/12/2022

Supervisor Signature	Josephine Borghi
Date	02/12/2022

5.3 Paper 2: Vulnerability pathways in essential health services: analysing the effects of system shocks on childhood vaccination delivery in Lebanon

Authors: Sharif A. Ismail^{1§}, Andrada Tomoaia-Cotisel², Aya Noubani³, Fouad M. Fouad⁴, Robert Sakic Trogrlic⁵, Sadie Bell¹, Karl Blanchet⁶, Josephine Borghi¹

Affiliations:

¹ Department of Global Health and Development, London School of Hygiene and Tropical Medicine, UK

² RAND Corporation, Santa Monica, United States

³ Independent Consultant, Lebanon

⁴ Faculty of Health Sciences, American University of Beirut, Lebanon

⁵ Advancing Systems Analysis Program, International Institute for Applied Systems Analysis, Laxenburg, Austria

⁶ Geneva Centre of Humanitarian Studies, Faculty of Medicine, University of Geneva, Switzerland

§Corresponding author:

Sharif A. Ismail

Department of Global Health and Development

London School of Hygiene and Tropical Medicine

London WC1H 9SH

Keywords:

Vaccination, vaccine, immunisation, humanitarian, children, Lebanon, refugee, Syria, systems, complexity, system dynamics, causal loop diagram, vulnerability, risk, hazard, resilience

5.3.1 Abstract

Shocks are under-theorised in the growing literature on health system resilience. Existing literature has focused on the effects of single shocks on discrete elements within the health system, typically at national level. Drawing from the disaster risk reduction literature, we explore the effects of multiple interacting shocks across system levels, using qualitative system dynamics modelling. We developed a causal loop diagram (CLD) to improve

understanding of how shocks can affect delivery of essential health services, using a case study on childhood vaccination delivery in Lebanon. Lebanon has experienced a series of shocks in recent years, including large-scale refugee influx from neighbouring Syria, COVID-19, a political-economic crisis and a large blast in the centre of Beirut in August 2020. We explored the effects of each shock individually, and in combination. The CLD was developed and validated using qualitative data from interviews with 38 stakeholders working in Lebanon's vaccination delivery system, ranging from national level policy to facility-level service delivery. Interviews were conducted between February 2020 and January 2022.

We found that each of the shocks had different effects on service demand- and supply-side dynamics. These effects cascaded from national through to local levels over time. Both Syrian refugee movement and COVID-19 primarily exposed vulnerabilities in service demand dynamics, mainly through slowly emerging knock-on effects on vaccination uptake behaviour among host communities, and fear of contracting infection in crowded health facilities respectively. The economic crisis exposed wider system vulnerabilities, including demand for vaccination as household income – and therefore ability to pay for vaccination – collapsed, and supply-side effects such as reduced clinic time for vaccination, declining workforce retention, and reduced availability of viable vaccine doses, among other pathways. Finally, important pathways of interaction between shocks were observed, particularly affecting the balance between demand for vaccination through publicly supported facilities rather than private clinics. Future research should incorporate dynamic approaches to identifying within-system vulnerabilities and their potential impacts under different scenarios, as a precursor to improved resilience measurement, system preparedness, and intervention targeting.

5.3.2 Introduction

Research and policy interest in understanding drivers of health system resilience has grown dramatically since the West African Ebola epidemic of 2014-16, but especially in light of the challenges systems worldwide have faced in responding to COVID-19 (14). There is growing consensus that health system resilience should be understood in terms of capacity to absorb, adapt or transform in response to a shock while maintaining essential structures and functions (10). However, the research literature on this topic remains exploratory, with ongoing uncertainty concerning resilience conceptualisation (9), optimal approaches to empirical investigation (28), and suitable intervention strategies to strengthen long-term system resilience (11,12,22).

In particular, shocks – as challenges to system resilience – are under-theorised in the health systems literature (28). This is a critical deficit because meaningful action to improve resilience

is impossible without some sense of what it is that a system should be resilient to. While a few studies do consider ways in which various shocks affect system resilience (spanning, for example, armed conflict, disease epidemics and economic crises), these analyses provide a limited view of how shocks interact with health system vulnerabilities and capacities to produce risks to health (2,14,267). Firstly, they present a static view, typically using the WHO building blocks. This approach ignores the dynamic interconnections between system elements. Secondly, existing literature tends overwhelmingly to adopt a macro-level, national lens (2,7,11,268), although there is increasing awareness following COVID-19 of the importance of dynamics at multiple health system levels (from local to national and even supra-national) (269,270). Thirdly, the literature has predominantly looked within the health sector alone for factors contributing to system resilience (11). There has been far less attention to cross-sectoral linkages which may give rise to “multi-systemic” risks over time (24). Finally, existing work on health system resilience tends to look at the effects of single shocks in isolation. In reality, health systems in many contexts (and especially humanitarian ones) must often address effects arising from multiple overlapping shocks at the same time. Work on multi-hazards in other fields has demonstrated how sequential shocks can interact to produce amplified, and sometimes wholly new, risks to human systems (16,17,271,272). Failure to adequately account for this may undermine health system resilience-building and preparedness efforts.

5.3.2.1 Insights on shock conceptualisation from domains outside health

Theoretical and empirical work in other fields offers a much richer view of shocks, emphasising the need to consider inter-relationships between different kinds of event, the interactions between them, and the risks they can give rise to across a range of social, political, economic, and environmental systems (28,273). These literatures invite us to move away from event-based typologies (distinguishing shocks caused by different types of climatic event, for example), towards instead characterising the attributes of shocks that are of relevance for determining health system effects. These may include [i] shock intensity, temporal and geographic scope, [ii] inter-relationships between shocks and the elements of the system of interest, and [iii] the role of path dependencies and other potential sources of vulnerability (e.g., institutional, poverty and other population vulnerabilities). Characterising shocks in this way, relies on methodological approaches that can capture change over time, and can model dynamic behaviour within complex systems (89,97,274).

Recent work in disaster risk reduction (DRR) and environmental science outlines how systemic risks can arise as a result of the combined effects of discrete shocks and interactions between these (275–277). It also shows how systems both shape shocks and are exposed to them. Combinations of shocks (compound shocks) can give rise to risks that are qualitatively

different from those that would have arisen had those shocks occurred separately in time and space (16,17,276,278–280). A key concept emerging from this literature for health systems is the notion of *cascading risk*, in which critical system vulnerabilities may be acted upon by a shock to create progressively amplifying impacts. The example frequently cited to illustrate this is Hurricane Katrina: a natural disaster that interacted with substantial pre-existing social, economic, political and institutional vulnerabilities in New Orleans in the United States, giving risk to catastrophic public health effects including more than 1,800 fatalities (271). This implies that – given the difficulty of predicting the range of macro-level shocks to a system that may occur – preparedness and resilience-strengthening work should instead focus on identifying and acting on recognised points of vulnerability within the system and addressing these .

In this study, we aimed to improve the theorisation of shocks as applied to health systems by conducting a focused case study on shock effects on delivery of an essential health service: childhood vaccination. Our case study was Lebanon, a country that has recently experienced a series of overlapping shocks in recent years. These shocks have included large-scale Syrian refugee influx, COVID-19, and a multi-dimensional political and economic crisis. Our focus was on better understanding interactions between the shocks, and the ways they affected activities at multiple levels (from national down to facility-level) to create within-system risks to vaccination delivery. In so doing, we present to our knowledge the first analysis of interactions between multiple shocks as applied to health systems.

We applied qualitative system dynamics modelling, a methodological approach that generates visualisations – causal loop diagrams (CLDs) – of cause-and-effect relationships within a system underpinning behaviour over time (see **Appendix 4**) (113,117). System dynamics has previously been applied to the analysis of resilience in health systems including in humanitarian contexts, but not to consider interacting shocks (110,111). A key emphasis of system dynamics is on capturing interconnections within systems and feedback processes (112). We used system dynamics in preference to other systems methods because our focus was at the aggregate system rather than the individual level. This method also enabled us to identify key variables and pathways (sequences of interconnected elements and feedback loops) mediating the impact of each shock on vaccination delivery. This included identifying points of interaction between the shocks over time, and system vulnerabilities exposed by each shock individually and in combination. Potential shock mitigation or adaptation measures and their implications are considered in the second paper in this chapter.

5.3.2.2 Vaccination delivery in Lebanon

This study was set in Lebanon, a small country in the Middle East covering around 10,500 km², and with an estimated population of just over 6 million in 2021 (200). Historically, the

health sector in Lebanon has been highly fragmented with powerful private and not-for-profit actors (223–227). Vaccination access points in Lebanon vary by population, but the primary delivery modes have been through private clinics and dispensaries (pharmacies), the charitable sector, the Ministry of Public Health's (MoPH) primary healthcare centre (PHC) network, and a network of Social Development Centres (SDCs) operated by the Ministry of Social Affairs (MoSA). Many dispensaries and all PHCs operate through partnership arrangements with local and/or international non-governmental organisations (NGOs) that provide financial, technical and other forms of support.

The Syria Crisis is the proximate cause of the latest in a long series of large-scale population displacements in Lebanon. There were around 825,000 registered Syrian refugees residing in Lebanon as of September 2022, down from a peak of just under 1.2m in April 2015. There is in addition a sizeable, unregistered refugee population, the magnitude of which remains uncertain. Palestinian and Syrian refugees together may account for around 24% of the Lebanese population. However, over the course of this study between 2019 and 2022, the country was engulfed by a compound crisis stemming not just from the population movement described above, but in addition an economic crisis and finally, from early 2020 onwards, the COVID-19 pandemic (see Chapter 3 for further detail). These three shocks have overlapped in space and time and interacted in particular ways to give rise to cascading risks to public services including vaccination delivery in Lebanon (206,281).

Time series data on administrative coverage for key antigens are indicative of large declines in national coverage broadly coinciding with the shocks described above (Figure 10). A key function of this study was to identify system vulnerabilities contributing to these trends.

5.3.3 Methods

This was a qualitative system dynamics modelling study drawing on analysis of transcripts of semi-structured interviews conducted with stakeholders in Lebanon between February 2020 and January 2022.

5.3.3.1 Approach to primary data collection

Study settings and participant recruitment

Interview participants were sampled purposively from organisations with a stake in routine immunisation delivery in Lebanon. These included representatives from government (the MoPH), from donors and agencies supporting the Lebanon Crisis Response Plan (LCRP), from NGOs supporting primary care service delivery, and finally from service managers and

practitioners involved in front-line primary care (see Table 3, but also section 4.3.2 for a fuller description of the categorisation for interviewee recruitment).

Facility-level interviews took place in two governorates in Lebanon: Beirut and Akkar. These locations were chosen to reflect the breadth of service delivery challenges across the country. Beirut incorporates the country's capital, the focal point for logistics and supply chains relevant to vaccination delivery, and has been the major hub for humanitarian actors, NGOs and others supporting the humanitarian response to the Syria crisis in Lebanon. Akkar is a border governorate in the North of the country which hosts a large refugee population and where a large proportion of the host community population are socio-economically deprived. It has also historically suffered from lower investment in public services than in other areas of Lebanon and has been among the areas worst affected by the economic crisis since late 2019.

Interview design and conduct

A total of 38 interviews were carried out in two waves (February-March 2020, and then July 2021-January 2022), n=8 of these in-person in Beirut, and the remainder remotely via Zoom. Interviews were semi-structured and gathered information on participant roles within the system, generic structures supporting vaccination delivery, and pathways and system behaviours that stakeholders identified as relevant to the various shocks. Interviews were recorded, transcribed into MS Word and where necessary translated from Arabic into English prior to analysis.

Table 5. Breakdown of interviews conducted, by stakeholder group and timing – paper 2.

The table also summarises the distribution of interview transcripts across the analysis and validation sets for CLD development.

Stakeholder group	Sub-category	Wave 1 (Feb-Mar 2020)	Wave 2 (Jul 2021-Jan 2022)	Analysis set	Validation set
National	Government	2	1	16	2
	Donors	0	4		
	Agencies	5	5		
	Private sector	0	1		
Regional bodies and implementing partner organisations		1	12	11	2
Local – facility level	Akkar	0	5	6	1
	Beirut	0	2		
Wave total		8	30		
Overall total		38		33	5

5.3.3.2 Generation of the CLD

The CLD was generated in three steps. First, a CLD was developed for each individual interviewee to represent their understanding of the effects of each of the shocks in Lebanon on childhood vaccination delivery. These were then combined using a stepwise process (outlined below), before a final validation step.

Step 1: generation of individual CLDs

Interview transcripts were split into two sets – a core analysis set from which the CLDs were derived, and a validation set to be used later (Figure 14). Individual interview transcripts from the core analysis set were coded in MS Word using purposive text analysis (252,253). This approach identifies language that is explicitly causal. Text segments were coded if they described events, processes or items (e.g., stocks of a particular good) relevant to vaccination delivery system responses to the arrival of refugees from Lebanon, or ongoing efforts to strengthen vaccination delivery across refugee and host community populations in the context of COVID-19 and the economic crisis in Lebanon. Finally, text segments were coded if they addressed relevant local (i.e., facility-level), meso- (i.e. regional) or macro-level (i.e. national) system behaviours.

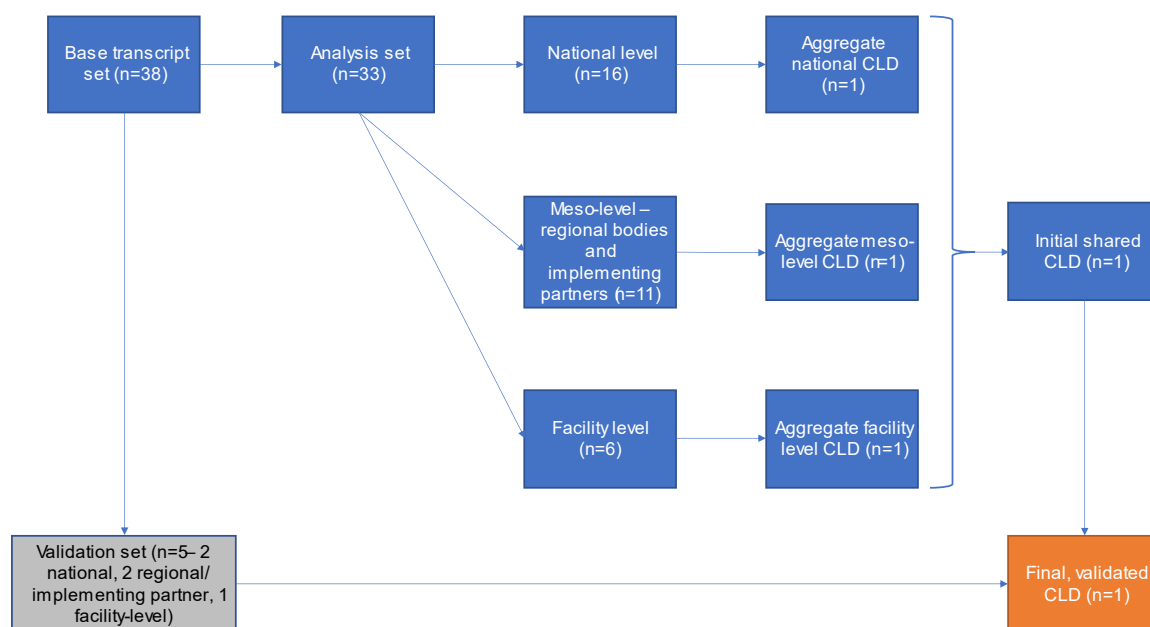


Figure 14. Schematic representation of the process for generating the initial, shared CLD from the analysis set. A total of $n=5$ interviews were set aside for use as part of the validation set, as outlined below.

Coded segments were then transferred into a separate MS Excel template for RIQs where they were deconstructed to identify relevant variables, causal language that linked one or more variables together, the directionality and polarity of these relationships, and whether any

significant material or information delays were identifiable (253). Variables and relationships identified in this way were then visualized in Vensim® (254). This process was repeated for each interview transcript in the analysis set, to develop a total of n=33 individual CLDs.

Step 2: combining CLDs

CLD combination followed a process described in Tomoaia-Cotisel (282). Individual diagrams were first grouped according to the stakeholder set from which they originated, and then ordered in terms of their complexity. The most complex CLDs within each stakeholder group were chosen as the base diagrams for combination for each stakeholder group, because they contained the richest information. These were termed the “anchor” CLD for each group, with which individual CLDs were combined, in order.

Before any combination was attempted, however, individual CLDs were first mildly pruned – a process in which extraneous links were removed to focus down on core variables and links between them. Only delays (any instance in which there was a material or information delay between two variables in a link) and feedbacks (any instance where there was a clear circular link or set of links between variables, whether positive or negative) were retained in this mild pruning process, following an approach set out by Yearworth (255).

Within each group, the anchor CLD was combined with the next most complex CLD. The process of combination was to compare the two CLDs with one another, and to identify variables and loops that were contained in the second CLD but missing from the anchor. These were then added to a copy of the anchor. Where two CLDs described the same causal process but in different ways, the more complex representation was retained on the basis that this was likely to give a fuller understanding of the causal structure involved in that section of the CLD. This process was repeated within and then across stakeholder groups to yield an aggregate diagram. A final, full pruning step was then carried out to retain only delays and feedbacks incorporating three or more links.

Step 3: validation and derivation of the finalised CLD

Validation consisted of two steps as described in Tomoaia-Cotisel (282). Saturation in CLD development was captured by tracking the number of additional variables, links and feedback loops introduced with each additional combination step (**Appendix 7**) (282). Since saturation was reached within the model development set of interviews, we proceeded to validate the draft, aggregated CLD, by reviewing interview transcripts from the validation set. These interviews were coded and analysed in the RIQ template to determine whether their contents confirmed the structure in the CLD, or whether revisions needed to be made (e.g., adding new variables, links, delays or feedback loops). Saturation was also reached within model validation set interviews, with limited modification to the structure through validation.

Appendix 7 provides the saturation curves for both model development and model validation set interviews.

5.3.3.3 Analysis and interpretation of the CLD

Once the validation process had been completed, the CLD was analysed to identify the shock effects and interactions and revealed system vulnerabilities described in section 5.3.4. Firstly, balancing and reinforcing feedback loops were identified based on the simple rule of thumb set out by Sterman (113), namely that:

- Balancing loops are those in which the number of negative links is odd;
- Reinforcing loops are those in which the number of negative links is even, or in which all links within the loop are positive.

To identify system vulnerabilities, links emerging from the shocks of interest (represented by variables such as “refugee influx”, “COVID-19 caseload”) were traced through the CLD to identify feedback loops and delays endogenous to the vaccination delivery system that were directly influenced by those variables. These correspond to the bold lines in the CLDs that follow in the remainder of this paper. Effects on these feedback loops were interpreted by reference to material in the original interview transcripts, and relevant quotes drawn from the RIQ template. Finally, points of interaction were identified where common feedback loops or delays were causally linked to more than one of the shocks.

5.3.3.3 Ethics

Ethical approval for the research project of which this study forms part was secured in the UK from the London School of Hygiene and Tropical Medicine (ref no 17461), and in Lebanon from the American University of Beirut (ref no SBS-2019-0376).

5.3.4 Results

We identified a series of causal pathways explaining effects linked to the three main shocks in Lebanon outlined above. Figure 15 provides a high-level overview of the vaccination delivery system, showing two loops representing connection between vaccine supply (loop R) and vaccination demand (loop B) in Lebanon. This simplified visualisation shows that each of the shocks acted on the system in different ways. While the refugee influx acted principally on actual demand for vaccination this occurred with a substantial delay, and both COVID-19 and in particular the economic crisis had wide-ranging effects on both the demand and supply sides of the system. Remaining sections below explore these effects in more detail.

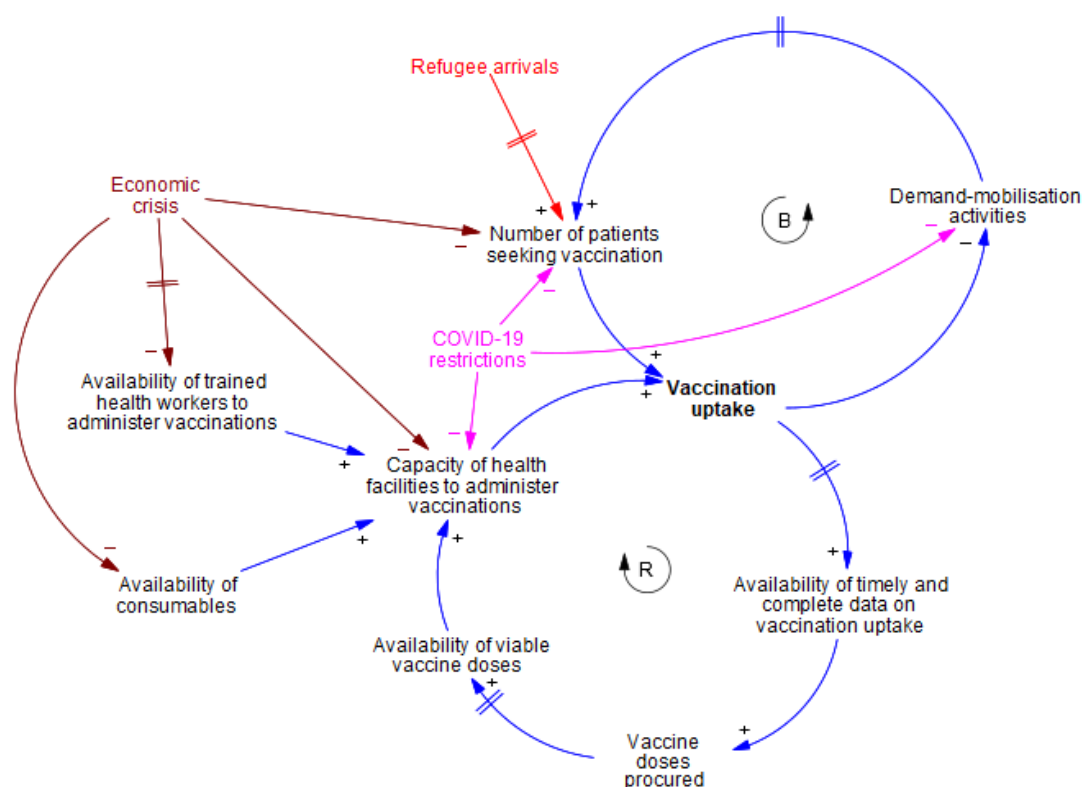


Figure 15. High-level CLD describing the effects of shocks on vaccination delivery in Lebanon.

In this visualisation, stable elements of the supply (R) and demand (B) sides of the vaccination delivery system in Lebanon are represented in simplified form in blue, feeding into the primary outcome (vaccination uptake); dynamics linked to the various shocks are highlighted in red.

5.3.4.1 Refugee arrivals from Syria

Initial system effects arising from refugee arrivals are visualised in Figure 16. Interviewees were clear that refugee arrivals did not immediately translate into increased demand for vaccination services. Many Syrians initially prioritised subsistence needs (e.g., food and shelter) over access to preventive services, and knowledge of service access points for childhood immunisation in the initial phases of the crisis was also limited. Additionally, a large proportion of refugees settled initially in informal settlements often some distance away from PHCs. This resulted in low demand through mainstream services early on, although there was some attempt to address emerging needs through use of mobile medical units (MMUs) that were conventionally used for outreach into remote areas.

Instead, a slowly unfolding cascade of effects at multiple system levels occurred over time. Effects were seen initially mainly at national level. Here, early system responses to refugee arrivals were motivated by growing concern at the perceived risk of VPD outbreaks, based on assumptions that the proportion of unvaccinated and partially vaccinated people in Lebanon was now rising. This perceived risk was also reinforced by reported VPD outbreaks in Syria.

This heightened concerns among decision-makers in Lebanon about the risk of an outbreak of a high-consequence VPD, particularly polio. It provided an additional rationale for the early, national vaccination campaigns that took place in 2013-14 (loop B1):

“Considering the polio outbreak in the neighbourhood countries, it was not possible for the Lebanese Ministry and for the sector also and the humanitarian agencies to wait until all these refugees settle and know where are the primary healthcare centres and go for their vaccines. It was very important for us to mobilise for the vaccination activities to go and reach them [with] door-to-door vaccination activities in order to prevent any major outbreaks and to help the system withstand all this pressure.”
[LFS01, agency representative]

As facility-level demand for vaccination services linked to population movement gradually increased in 2014-15, vulnerabilities within the system became more apparent. Better awareness of PHC locations and the fact that Syrian refugees could obtain vaccinations there free of charge spurred an increase in PHC attendance and in some cases facility-level crowding, occasionally resulting in clinic closures when staff felt demand outstripped local capacity to administer vaccines (loop B1). Vaccination uptake was also influenced by declining availability of clinic time to vaccinate, as health worker workload in PHCs and other primary care facilities increased (loop B2). The perceived risk of facility-level vaccine stock-outs also increased demand for vaccination (loop B3), although interviewees emphasised that in general supplies of vaccine doses to facilities had kept pace with emerging needs following the main period of cross-border movement from Syria.

Rising demand for vaccination through PHCs driven by increasing attendances by Syrian refugees also spurred an important shift in vaccination uptake behaviour among host communities. Historically, host communities across income groups had sought vaccination predominantly through private clinics, because of a perceived link between cost and quality of care (loop R1). Rising use of PHCs by Syrians and resulting facility crowding resulted in private clinics being perceived to offer better quality care than PHCs, which catered mainly to refugees.

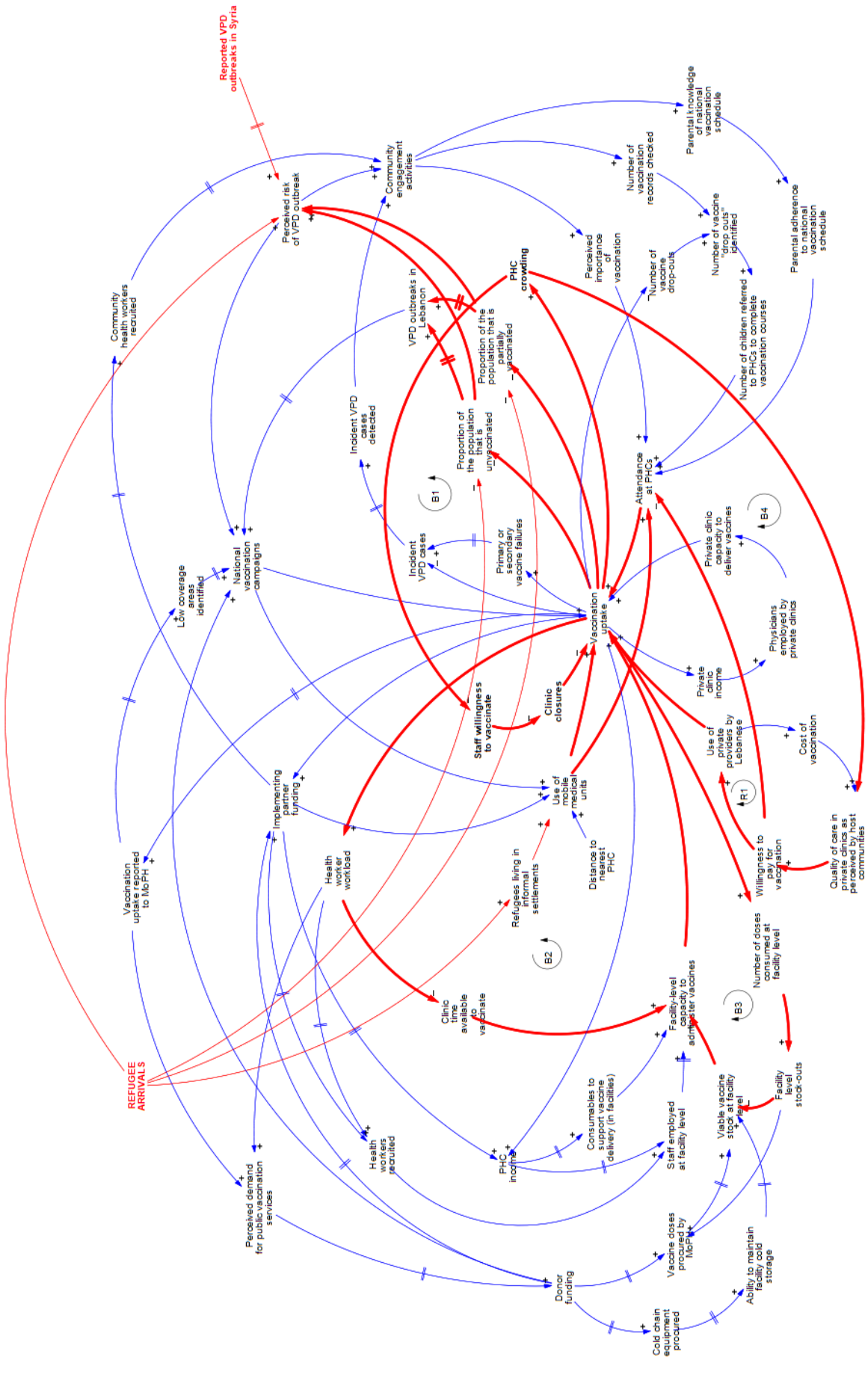


Figure 16. CLD showing pathways of impact within the vaccination delivery system in Lebanon following the arrival of refugees from Syria.

In this diagram: direct effects arising from the movement are captured using red variable labels and thin red lines; intermediate links connecting direct effects to downstream health system pathways are, where relevant, shown in bold green lines; and pre-existing system pathways directly activated by the shock are shown in bold red lines. Lighter blue lines correspond to usual pathways and relationships between system components (when operating under “normal” conditions). Loops labelled “R” are reinforcing; those labelled “B” are balancing. Only loops directly linked to sources of vulnerability are labelled. [Abbreviations: MoPH = Ministry of Public Health; PHC = Primary Healthcare Centre; VPD = Vaccine Preventable Disease]

This reinforced the historical preference of host communities for vaccination through private clinics (loop B4).

“Syrians overwhelmed the centres...so the Lebanese who used to go to those centres stopped going, and the Lebanese do not get their vaccinations in those centres, who mainly go to the private sector.” [LFSE1, agency representative]

“The Lebanese population know where are the centres. But they don’t prefer to go to the centres. This is because unfortunately of a lack of trust to the public system. So you can find a Lebanese family that’s somehow poor, or moderate, in need of financial support. However, they prefer to pay, I don’t know to borrow \$100 from a neighbour and take their children to get vaccinated in a private clinic, and they don’t go to get the free vaccination in the PHC next door.” [LFS06, agency representative]

COVID-19 related effects were seen principally at the micro-level, affecting both demand for, and supply of, services. From a demand perspective, a new causal pathway emerged linking ability to socially distance in facilities to carers’ perceived risk of contracting COVID-19 which in turn reduced vaccination uptake as clinic attendances declined (loop B5). This was mirrored by a new supply-side loop in which health workers’ perceived risk of contracting infection increased the likelihood of clinic closures, reducing access to vaccination (loop B1 adj.). Perceived risk of contracting COVID-19 was linked to both facility-level crowding, and knowledge of the background caseload. The result was de-prioritisation of preventive services including vaccination:

“Even if we have been given lists of defaulters by the MOPH, when we contact the family and find a defaulter and try to persuade the family to attend a PHC, then we find there is fear or areas or health services where there is perceived to be a risk of contracting the virus e.g. at the health centre or hospital, then they say they would prefer to go the PHC later, or they may say that they don’t think it is important” [LFS08, implementing partner]

5.3.4.2 COVID-19

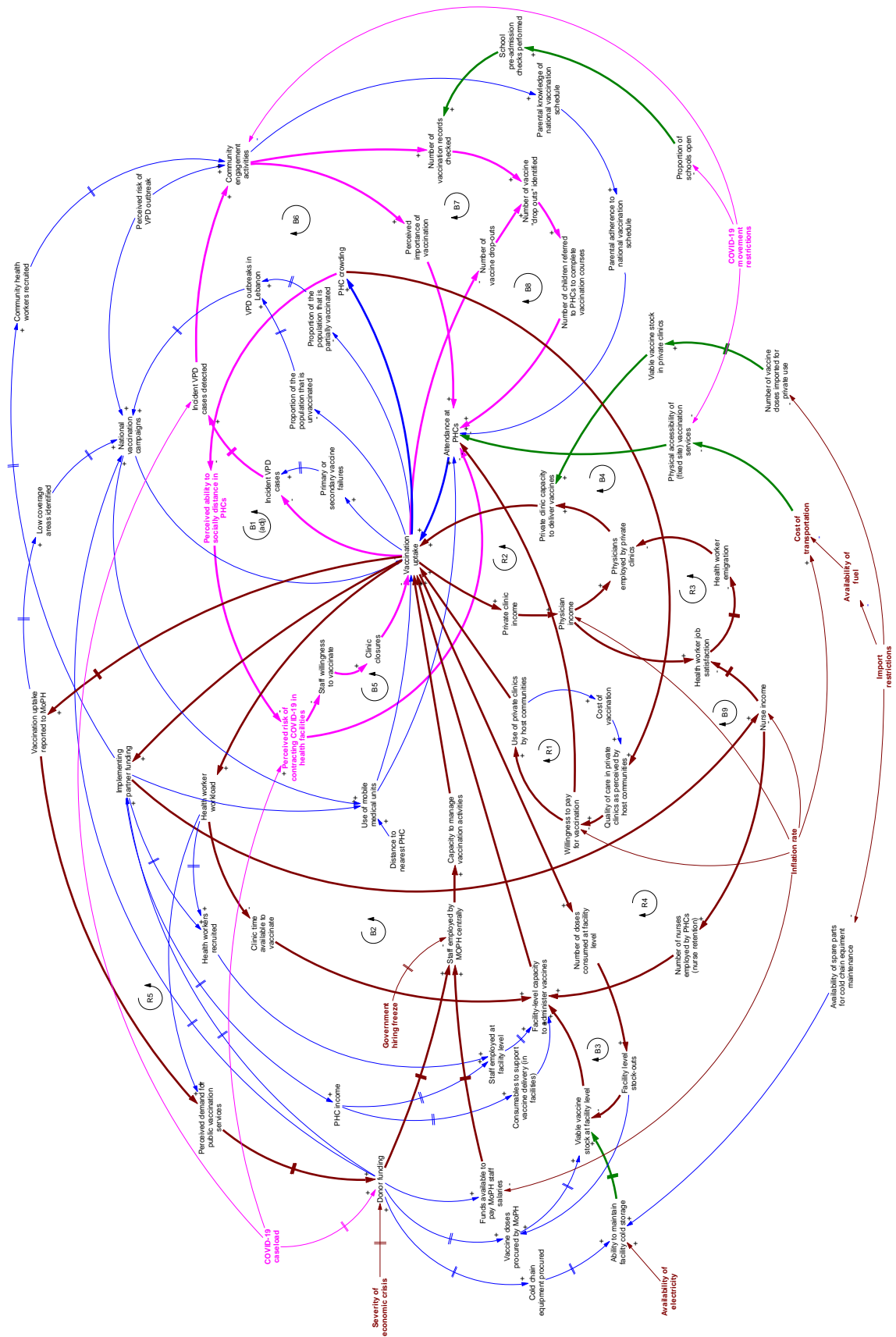


Figure 17. CLD visualising effects arising from the shocks that took hold in Lebanon from autumn 2019 onwards. In this visualisation, effects involving the economic crisis and COVID-19 are modelled concurrently owing to the close temporal overlap between these shocks and their impacts. Proximate effects involving COVID-19 are shown in light pink text and light pink lines, while key within-system pathways affected are shown using bold pink lines. A similar colour-coding approach is used for effects linked to the economic crisis, shown in brown.

At the macro-level, several interviewees highlighted systemic vulnerabilities created by the re-allocation of MoPH resources to COVID-19 response and away from VPD case surveillance. Interviewees in wave 2 expressed concern that this increased the risk of VPD cases emerging undetected. They highlighted that without adequate surveillance, there was a risk that response work using community engagement to increase demand for vaccination in areas where new cases had been identified would not be triggered in a timely way (loops B6, B7):

“During COVID all the [Epidemic Surveillance Unit] systems and the active surveillance were focusing more on COVID, so the active surveillance was not properly done so we don’t know if there were really acute flaccid paralysis cases that were not properly detected...” [LFS11, government official]

COVID-19 movement restrictions had wide-ranging effects on demand for vaccination from host communities and refugee populations alike. Clinic attendances fell precipitously especially during the first lockdown because of these restrictions – although as the CLD shows this pathway was not, in the view of interviewees, fully endogenous to the vaccination delivery system. School closures also disrupted a key point of verification of children’s vaccination records, a process that typically happened at the beginning of the school year. Several interviewees highlighted the impact this had had on ascertainment of children with incomplete vaccine courses, and system capacity to address this (loop B7).

Movement restrictions also hampered the effectiveness of community engagement activities to increase demand for vaccination. Implementing partners consistently highlighted the impact that changing from face-to-face to remote community engagement work had had on their ability to engage target populations, in turn influencing ability to emphasise the importance of vaccination and to identify children who had not received per-schedule vaccines:

“In the peak of the pandemic in Lebanon, we were so frustrated because we shifted to the online modality and even if you know you are so motivated and so engaged, you cannot have this impact as when you are physically present in the household...interacting with them” [LFS10, implementing partner]

Although second wave interviewees emphasised that demand had recovered to some extent as COVID-19 restrictions were eased, this recovery was only partial because of worsening economic conditions – as the next section will show.

5.3.4.3 The economic crisis

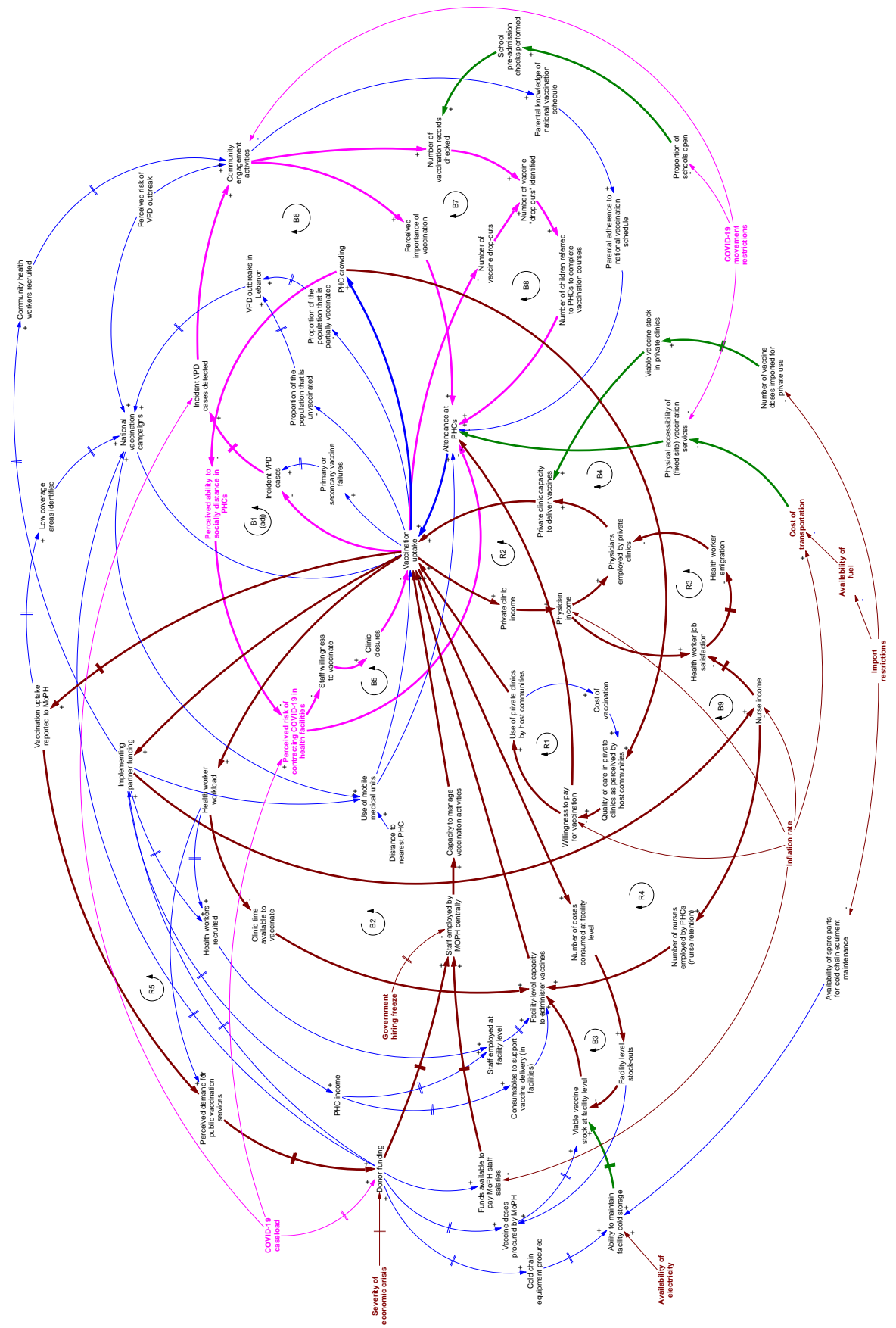


Figure 18. CLD visualising effects on both demand and supply linked to the economic crisis.

The figure shows that these occurred through multiple system leverage points, reflecting the complexity of effects in a range of interconnected systems that the economic crisis gave rise to. At a macro level, the Lebanese government's worsening fiscal position prompted the imposition of a civil service hiring freeze from 2017 onwards – the first manifestation of the economic crisis. Interviewees highlighted the detrimental effect this had had on central capacity in the MoPH as staff attrition progressively reduced the workforce available to manage the national vaccination program, and to act on increasing service demand (loop R5).

From a vaccine supply perspective, a majority of interviewees highlighted concerns regarding the impact of increasingly irregular electricity supplies on cold chain integrity. This was linked variously to failures in the domestic power grid in Lebanon, the rising cost of fuel for backup generators and the effect of import restrictions on the availability of spare parts for solar-power fridges widely used in PHCs by 2019-20. Inability to maintain sufficient cold storage at facility level reduced the availability of viable doses locally, and therefore the capacity to administer vaccines (loop B3). Irregular electricity supplies also reduced capacity to deliver simply through reductions to clinic working hours because managers could no longer afford to keep facilities open.

A key driver of vulnerability at multiple levels across the system – and affecting both demand and supply – was the declining value of the Lebanese Lira:

“To be honest, I don't believe that nowadays with this dollar inflation, that the PHCs alone can act, or the MOPH or the government alone can act without the humanitarian support or donors, it's impossible for the system to run” [LFS12, implementing partner]

Nationally, currency inflation intensified the workforce retention problem at central level (loop R5). Inflation reduced funds available to pay salaries and the value of those salaries. At facility level, the rapidly declining value of salaries contributed to worsening health workforce retention. Interviewees highlighted the difficulty of trying to recruit and train replacement staff under current conditions:

“Every day we are losing some staff and vaccinators...because they are not satisfied any more with their salaries. They used to be paid for example US\$600 now they are paid US\$50, so some of them are leaving to work abroad and we are losing a lot of them that PHCs and dispensaries... we are trying to train again and again new staff and this staff needs also experience and not only experience in how to provide the vaccine but also in communication and how to know their community and how to deal with people” [LFS11, government official]

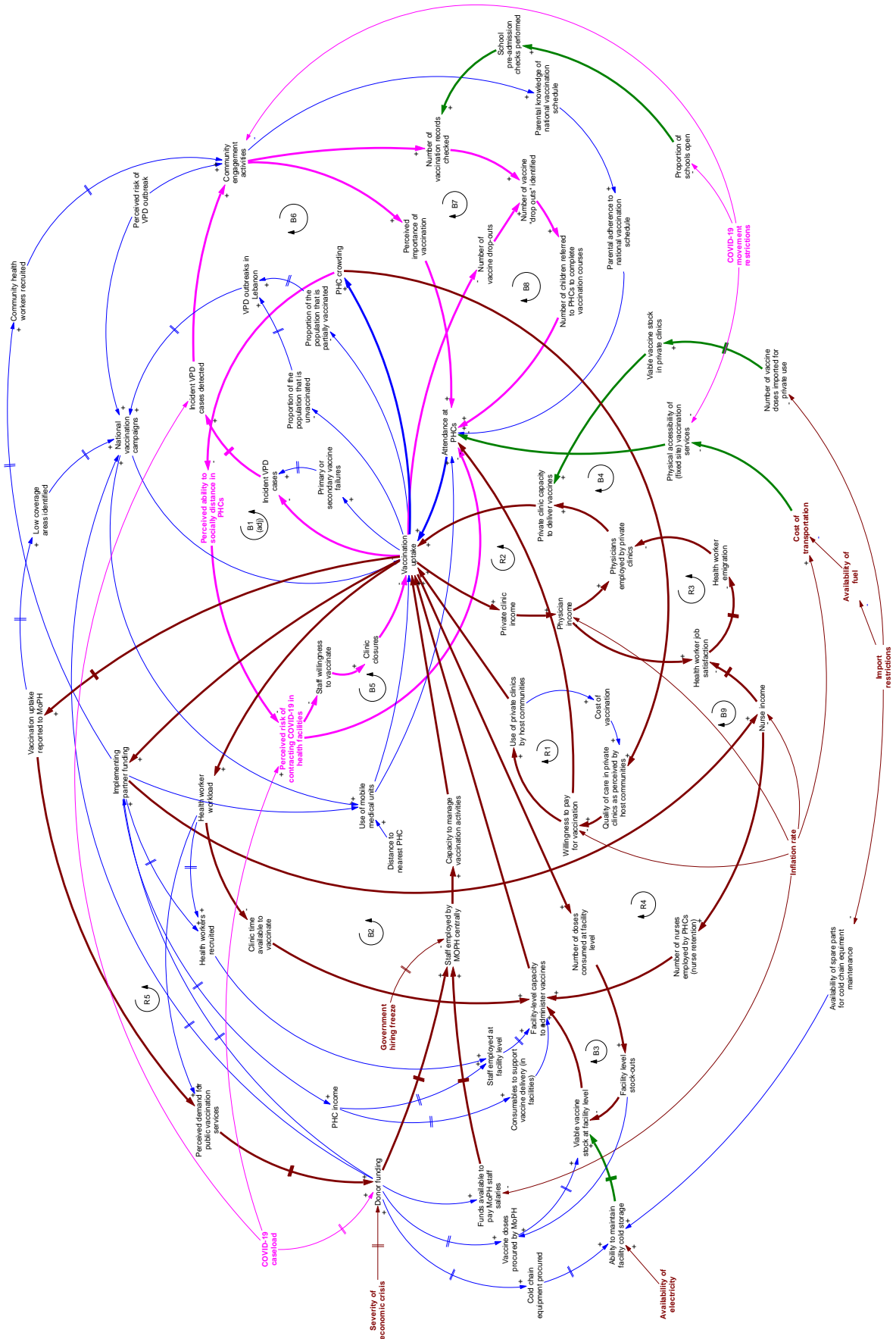


Figure 19. CLD showing pathways of impact within the vaccination delivery system in Lebanon linked to COVID-19 and the economic crisis.

In this diagram: proximate effects linked to COVID-19 are shown in light pink text and light pink lines; intermediate links connecting direct effects to downstream health system pathways are, where relevant, shown in bold green lines; key within-system pathways affected are shown using bold pink lines. A similar schema is used for effects linked to the economic crisis, but in brown. Lighter blue lines correspond to usual pathways and relationships between system components (when operating under “normal” conditions). Loops labelled “R” are reinforcing; those labelled “B” are balancing. Only loops directly linked to sources of vulnerability are labelled. [Abbreviations: MoPH = Ministry of Public Health; PHC = Primary Healthcare Centre; VPD = Vaccine Preventable Disease]

Those that could – predominantly medical doctors – looked for opportunities to emigrate. This had implications particularly for private clinic capacity to vaccinate because they relied mainly on physician-led administration of vaccines (loops R2 and R3). The declining value of nurse salaries also contributed to workforce attrition (loop B9), and although this was reported by interviewees to be less significant in numerical terms than among doctors, it contributed to a worsening problem of unsustainable workloads for clinic staff in the PHC network (loop B2).

From a service demand perspective, rising inflation (and resultant declines in household income) had two main effects. Firstly, it reduced host community willingness to pay for vaccination through private clinics because of the cost to households. Secondly, it increased the relative cost of transport to health facilities. The former spurred a surge in vaccination uptake by host communities through PHCs where costs of vaccination and other essential health services were much lower (loop B4). The latter to some extent counteracted this effect by increasing barriers to accessing fixed sites, especially when combined with the effects of COVID-19 movement restrictions.

5.3.4.4 Shock interactions and their effects

Although refugee arrivals were separated to some extent in space and time from COVID-19 and the economic crisis, interactions did occur in some key sectors of the CLD. These reflected effects on common vulnerability pathways. This section focuses on two example CLD sectors that were affected by at least two of the shocks.

Interactions amplifying vulnerability within a loop: PHC crowding and vaccination uptake

Figure 20 shows a central loop from the CLD on which two of the shocks acted together to reduce vaccination uptake. As outlined above, refugee arrivals from Syria gradually drove an increase in demand for vaccination, but this took time to emerge. As it did so, rising PHC attendances contributed to facility-level crowding, and in some cases clinic closures, as demand outstripped the capacity health workers perceived they had to administer vaccines (loop B1). This reduced uptake especially among host communities. COVID-19 produced a similar dampening effect although the mechanism was different. Here, crowding increased

service-user and health worker fears of contracting infection in facilities, which reduced supply as clinics were closed (loop B1 adj.) and reduced demand as service-users opted not to attend (loop B5). In the context of the pandemic, the effect was also universal across host communities and refugee populations.

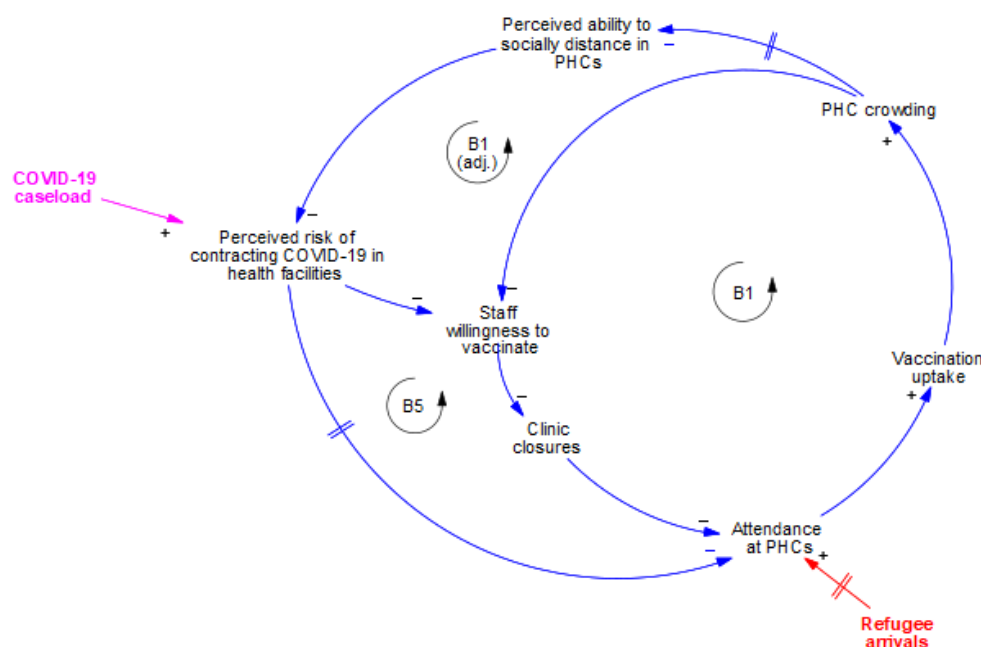


Figure 20. A series of nested pathways influencing demand for vaccination, shown as a series of balancing loops. Key points of interaction with each of the relevant shocks (refugee influx and COVID-19) are given in red and pink text and lines respectively. Delays – in this case affecting the relay of information between different parts of the system – are indicated by hashed lines.

Interactions producing a change in vaccination demand behaviour

One illustrative series of loops helps to understand the balance between vaccination uptake through PHCs and private clinics, principally by host communities. Here, sequential shocks acted on existing vulnerabilities to produce a shift in population behaviour (Figure 21). Interviewees consistently noted a basic preference among host communities for vaccination in private clinics despite higher cost, founded on an assumed virtuous link between cost and quality of care in these settings (loop R1). Following the major cross-border movements from Syria, however, attendance at PHCs by Syrian refugees gradually increased, contributing in time to facility crowding. Perceived quality of care in private clinics relative to PHCs among host communities rose further because of this (loop R3). The effect was to reinforce the core, positive feedback loop in R1 (panel A). The effect of rising COVID-19 caseloads appears to have further intensified this dynamic. Concerns over PHC crowding and perceived risk of contracting infection in these facilities imposed further restraints on PHC attendance for vaccination (loop B1 adj.).

However, interviewees indicated that the economic crisis reversed the basic pattern of host community behaviour described in loop R1. Collapsing household incomes reduced willingness to pay for vaccination so that a reinforcing loop favouring PHC attendance for vaccination (loop R5) now dominated over what had been the core loop (panel B).

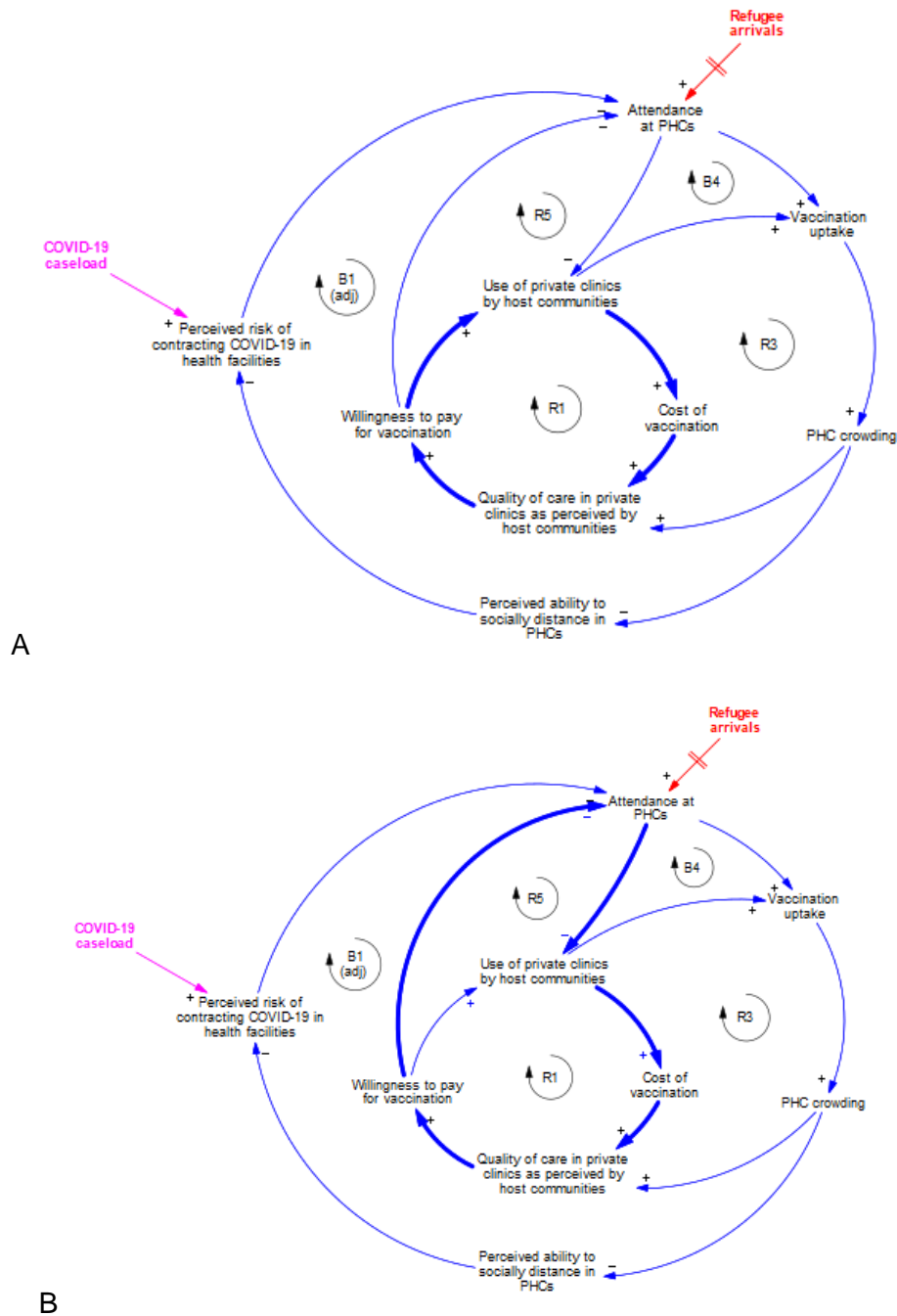


Figure 21. A series of interacting loops describing household-level behaviour influencing demand for vaccination through PHCs and private clinics.

Intervention points for the various shocks are highlighted using coloured text and arrows. Panel A highlights the dominant loop (loop R1) influencing host community service access behaviour following the refugee influx and in the context of COVID-19. Panel B shows how the dominant loop shifted as declining household income altered clinic attendance behaviour.

5.3.5 Discussion

In this study, we used CLDs to describe effects linked to a series of shocks on the Lebanese routine vaccination delivery system. While near-term effects of each of these shocks were exogenous to the vaccination delivery system, each interacted with existing system structures in multiple ways and at multiple levels, amplifying pre-existing sources of vulnerability.

Refugee arrivals from Syria contributed mainly to changes in patterns of demand for routine immunisation. However, these took time to feed through because of a combination of [i] lack of obvious access points for Syrian refugees at the beginning of the crisis, [ii] initially limited awareness among new arrivals of how to navigate the (complicated) network of providers in Lebanon, and [iii] the initially low priority accorded to preventive health services by refugees. COVID-19 and the economic crisis influenced supply and demand dynamics in important ways, but the economic crisis had by far the most wide-reaching effects of all of the three shocks in terms of the scale and scope of its impact on vaccination delivery. The economic crisis affected everything from retention of staff at central level (and in turn capacity to manage the national vaccination program) through to staff numbers and cold chain integrity at facility level, and influenced demand dynamics especially for host communities in Lebanon. By contrast, the Beirut blast of August 2020 did not feature prominently in interviewees' accounts. Effects on vaccination delivery from this event appeared to have been largely limited to Beirut, and contingencies were rapidly put in place to offset some of the greatest risks arising from it. One example was the relocation – within 24 hours – of the national vaccine store from a destroyed warehouse in the port area to a public hospital in Beirut.

We identified a series of pathways or points in the system that proved to be sources of vulnerability for some or all of the shocks in Lebanon. These were predominantly at facility level. A series of feedback loops linked facility-level crowding to reduced vaccination uptake via either demand problems (concerning service-user perceived risk of contracting COVID-19 in PHCs), or supply issues (concerning staff willingness to vaccinate patients, or staff-perceived risk of contracting COVID-19). Analysis of a second set of connected feedback loops relating uptake through private clinics and PHCs demonstrated how dominant behaviours in part of the delivery system can shift in response to different shocks. Here, a historical host community preference for vaccination through private clinics was amplified by refugee arrivals and COVID-19 but then reversed by the economic crisis because people could no longer afford to pay for vaccination. From a demand perspective, willingness to pay for vaccination was a key determinant of service user behaviour for host communities. Interviewees contrasted this with expectations among Syrian refugees, who arrived from a country with a long-standing history of providing childhood immunisations through public providers, pre-conflict. Facility-level crowding also proved a key driver of both demand- and

supply-side behaviour by influencing both perceived risks (e.g., contracting COVID-19 infection) and perceived service quality. From a supply perspective, the key vulnerability pathways influencing facility-level capacity to administer vaccines concerned health worker workload, and the availability of viable vaccine stock locally.

Findings also point to detrimental effects arising from an accumulation of risk over time owing to sequential shocks. While aggregate assessments of vulnerability or resilience should be handled cautiously, there were growing indications from interviews towards the end of the second wave that the intensification of risks especially under the pressures of the economic crisis was pushing the vaccination delivery system towards a tipping point beyond which vaccination delivery might no longer be sustainable. Evidence for this included the combination of effects on both supply- and demand-side dynamics, at multiple system levels, and over and above those already exposed by refugee arrivals and by COVID-19, and in trend data on population vaccination coverage from Lebanon. Clearer – potentially quantitative – determination of points at which cumulative risk pushes systems towards tipping points is an important area for further development. Analysis of the impact of sequential shocks and their implications for resilience has been scant in the health systems literature, and while their importance is increasingly recognised in other fields there is broad acknowledgement that currently available analytical tools are not well attuned to capturing accumulating risks of this kind (283).

To the best of our knowledge, this is the first study to consider vaccination delivery system responses to shocks using a dynamic approach grounded in systems thinking. While a handful of prior studies have mapped out system effects linked to single shocks – including in response to the Syria crisis (110,111) – this is also the first health systems study to consider how effects from multiple, overlapping shocks can exacerbate vulnerabilities. It is also, to our knowledge, the first study to consider health system effects arising from the economic crisis in Lebanon. Our findings suggest a series of pathways by which risks arising from each of the shocks were propagated from national through to local levels, in line with Pescaroli and Alexander's description of cascading disasters (271). An important methodological strength of this analysis was the application of system dynamics, enabling the identification of causal pathways linking exogenous shocks to feedback loops integral to the system structure, and enabling a qualitative assessment of how these were differentially affected by each shock (248).

Key findings also support those found in the relatively small number of empirical studies of resilience published elsewhere, but add important new insights. Previous analyses considering system resilience in humanitarian settings have predominantly focused on service delivery in the round (110,111), or on domains such as mental health (251). The second of

these studies identified human resource attrition and declining motivation as major threats to long-term system resilience in a conflict-affected setting, as well as threats to service uptake because of fear in a context of insecurity (110). Our findings – from a humanitarian setting but one in which insecurity was much less of a feature – reinforce the importance of health workforce retention and the role of fear (e.g., of COVID-19) in driving service demand, but also point to wider factors including availability of key commodities (in this case, vaccine doses).

There are a number of limitations to the analysis. First, a full exploration of demand-side dynamics affecting system behaviour over time was not possible because data collection focused on policymakers and service providers only and did not extend to service users. This decision was made pragmatically given the challenge of adequate sampling for interviews across service user groups in Lebanon, and the enormous difficulties of on-the-ground data collection at the time of the study in light of COVID-19 restrictions and growing domestic political and economic instability.

Secondly, given that data collection commenced in early 2020, and most Syrian refugee movement into Lebanon occurred in the period 2014-15, there is a risk of recall bias in the findings reported here. A number of steps were taken to address this risk, including [i] explicitly asking interviewees to highlight areas in which they were not confident their recollection was correct, or during which they had been working in other roles not directly relevant to vaccination delivery; [ii] recruiting participants with varying degrees of experience in the system, ranging from a few years to in excess of 20 years in several cases; and finally [iii] recruiting participants working at various system levels.

Thirdly, data analysis was performed largely by the lead author, potentially introducing bias into CLD development. Various safeguards were built into the study design to address this, including [i] the application of purposive text analysis as a structured approach to analysis of interview transcripts; [ii] the use of a standardised RIQ template for quote interpretation; [iii] CLD combination using a clearly documented process in which the order of combination was determined based on a quantitative appraisal of diagram complexity; and most importantly [iv] validation of a draft, aggregated CLD using both a dedicated set of interview transcripts.

Finally, while CLDs allow us to infer important system behaviours, they cannot deduce them (123). For this, formal simulation modelling is required. Simulation modelling was not attempted as part of this study and is an area for future development.

5.3.6 Conclusion

This study has shown how a series of shocks in Lebanon, overlapping to varying degrees in space and time, interacted with existing system structures to reinforce existing, and create new, risks for vaccination delivery. In particular, it has shown how the compound nature of recent shocks significantly amplified risks in specific parts of the vaccination delivery system, pointing to potential leverage points for action. Future research should consider both the generalisability of these to other service areas and contexts, and consider intervention approaches that might meaningfully address vulnerabilities in the interests of long-term system resilience.

5.3.7 Back matter

5.3.7.1 Acknowledgements

The authors offer thanks to all the participants in this work, who gave generously of their time during an extremely challenging period in Lebanon. We also thank officials in the Department of Primary Care at the Lebanese Ministry of Public Health for supporting the study and in particular for facilitating access to staff in primary care facilities.

5.3.7.2 Funding

The research described in this paper was supported by a Wellcome Trust Clinical Research Fellowship awarded to the lead author (ref no 215654/Z/19/Z).

5.3.7.3 Conflicts of interest

The authors report no conflicts of interest.

5.4 Research paper cover sheet – paper 3



London School of Hygiene & Tropical Medicine
Keppel Street, London WC1E 7HT

T: +44 (0)20 7299 4646

F: +44 (0)20 7299 4656

www.lshtm.ac.uk

RESEARCH PAPER COVER SHEET

Please note that a cover sheet must be completed for each research paper included within a thesis.

SECTION A – Student Details

Student ID Number	1806401	Title	Dr
First Name(s)	Sharif Adel		
Surname/Family Name	Ismail		
Thesis Title	Resilience to shocks in national vaccination delivery systems: from analysis of shock effects to resilience-strengthening intervention approaches in Lebanon		
Primary Supervisor	Professor Josephine Borghi		

If the Research Paper has previously been published please complete Section B, if not please move to Section C.

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?*	Choose an item.	Was the work subject to academic peer review?	Choose an item.

*If yes, please attach evidence of retention. If no, or if the work is being included in its published format, please attach evidence of permission from the copyright holder (publisher or other author) to include this work.

SECTION C – Prepared for publication, but not yet published

Where is the work intended to be published?	Health Affairs
Please list the paper's authors in the intended authorship order:	Sharif A. Ismail, Andrada Tomoia-Cotisel, Aya Noubani, Fouad M. Fouad, Sadie Bell, Josephine Borghi, Karl Blanchet

Stage of publication	Not yet 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. (Attach a further sheet if necessary)	I conceived the study; designed the study with methodological input from AT-C, JB and KB; collected the data with support in Lebanon from AN; performed the data analysis with methodological input from AT-C; drafted the full manuscript; revised the manuscript with supervisory input from JB, KB and SB, and incorporating revisions from all authors.
--	---

SECTION E

Student Signature	Sharif Ismail
Date	02/12/2022

Supervisor Signature	Josephine Borghi
Date	02/12/2022

5.5 Paper 3: Resilience in childhood vaccination: analysing delivery system responses to shocks in Lebanon

Authors: Sharif A. Ismail^{1§}, Andrada Tomoaia-Cotisel², Aya Noubani³, Fouad M. Fouad⁴, Sadie Bell¹, Josephine Borghi¹, Karl Blanchet⁵

Affiliations:

¹ Department of Global Health and Development, London School of Hygiene and Tropical Medicine, UK

² RAND Corporation, Santa Monica, United States

³ Independent Consultant, Lebanon

⁴ Faculty of Health Sciences, American University of Beirut, Lebanon

⁵ Geneva Centre of Humanitarian Studies, Faculty of Medicine, University of Geneva, Switzerland

§Corresponding author:

Sharif A. Ismail

Department of Global Health and Development

London School of Hygiene and Tropical Medicine

London WC1H 9SH

Keywords:

Vaccination, vaccine, immunisation, humanitarian, children, Lebanon, refugee, Syria, health systems, complexity, system dynamics, causal loop diagram, resilience, absorption, adaptation, mitigation, transformation

5.5.1 Abstract

Although academic and policy interest in health system resilience has grown considerably in recent years, the empirical literature on this topic remains small and predominantly focused on macro-level (national) effects arising from single shocks. To better understand health system responses to multiple shocks, we conducted an in-depth case study using qualitative system dynamics. We focused on routine childhood vaccination delivery in Lebanon in the context of at least three shocks overlapping to varying degrees in space and time: large-scale refugee influx from neighbouring Syria; COVID-19; and an economic crisis. Findings were

drawn from analysis of 38 semi-structured interviews with stakeholders working at different levels in the system, transcripts for which underwent purposive text analysis to generate a causal loop diagram (CLD) mapping out relationships between system variables contributing to changes in coverage for routine antigens over time. The CLD was validated using a reserve set of interview transcripts. Using the CLD, we identified a range of system responses to the shocks, including demand-promotion measures such as scaling-up community engagement activities and policy changes to reduce the cost of vaccination to service users, and supply-side responses including mobilisation of donor funding, diversification of service delivery models and cold-chain strengthening measures. A smaller set of systemic changes were introduced – particularly in response to refugee arrivals – and included task-shifting to nurse-led vaccine administration. Some potentially transformative change was seen at meso- and micro-levels and depended on changes in both demand- and supply-side dynamics. Some resilience-promoting measures introduced following earlier shocks appear to have increased vulnerability to later ones, highlighting the need for *ex ante* evaluation of potential unintended consequences arising system interventions under different shock scenarios.

5.5.2 Introduction

While academic and policy interest in health system resilience has grown exponentially in recent years, the literature on this topic remains emergent and empirical analyses of resilience are few in number (11). This is especially the case for humanitarian settings, where challenges to system resilience can be particularly acute. Resources to support meaningful responses in these settings – whether human, financial or others – are often more limited, more unpredictable, and typically more dispersed than in stable settings. Partly because of the ongoing lack of consensus on approaches to conceptualising resilience, there is also considerable uncertainty over how best to strengthen it, although there is broad acknowledgement that doing so must extend beyond the more limited aims of health system support or even health system strengthening (21,22,187).

The need for empirical analysis of health system resilience in humanitarian settings to inform intervention strategies is increasingly urgent. Delivery of essential services such as vaccination in these settings is challenging and liable to disruption, although its effectiveness for population health is well-established (43). Maternal and child health outcomes in humanitarian settings often fall well below those observed in stable settings. There is consistent evidence that childhood vaccination coverage for key antigens is among the lowest in the world for countries affected by conflict or other forms of humanitarian crises (49,50). And while there is growing evidence on interventions to improve health outcomes in humanitarian contexts (85,284), most existing guidance is focused on acute-phase response

(82,83). Insights on measures to strengthen longer-term system resilience in these settings are more limited.

Defining health system resilience is a key first step in identifying measures to strengthen it. Classical definitions of resilience conventionally emphasise capacities to absorb shocks, adapt or even transform in response to them, while maintaining broad system structures and continuing to deliver essential services (10). Absorption can broadly be understood as a process in which no structural change occurs: the shock is simply accommodated using existing structures and pathways (10). Adaptive responses can involve some circumscribed structural or pathway changes in response to a shock. However, they are qualitatively distinct from transformation, in which learning is harnessed to fundamentally alter the structure of the system and strengthen it for the future, with or without goal re-orientation (18,137). In this analysis, focusing on childhood vaccination delivery in Lebanon, resilience was assessed in terms of overall ability of the system to maintain, and where possible improve, population vaccination coverage for measles (i.e., first and second doses of measles-containing vaccine, or MCV1 and MCV2).

Although each of these aspects of resilience describes a process of change, most work in health systems research to date has adopted a static view focused on discrete resilience capacities (such as networking between system actors, the presence of multiple, alternate service pathways, or “collaterals”, and others) (7,14,18). A small number of studies have mapped out system vulnerabilities and mitigation measures in a dynamic way – both in humanitarian settings (110,111). However, applications of dynamic perspectives to resilience analysis are limited. Finally, empirical explorations of transformation in health are very few (11). What system transformation means in practice continues to be a source of debate in other research disciplines (28).

In this study, we used qualitative system dynamics (SD) to understand system responses to shocks because this approach focuses on aggregate-level behaviours contributing to outcome trends, and in particular, the importance of feedback in explaining why systems behave as they do (112,113,117). The aim of this analysis was to identify vaccination delivery system responses and mitigation strategies to sequential shocks in Lebanon. Paper 2 above (section 5.3) addresses pathways of shock impact. Here, we sought to describe both responses intrinsic to system structures and those actively promoted via, for example, policy change – as well as the unintended consequences of these responses. We also considered responses across system levels. Finally, we considered the effects of interventions to support responses to earlier shocks, on system resilience against later ones. The purpose for doing so was to identify points and pathways in the system through which responses were implemented, and

to consider what was learnt from efforts to strengthen resilience over time. Although our analysis touches on demand-side behaviours, the specific focus of our analysis was on supply-side (service delivery) changes.

5.5.2.1 Study context

This study was set in Lebanon, a small Middle Eastern country with an estimated population of just over 6 million in 2021 (200). The health sector in Lebanon has historically been fragmented with a dominant role for private providers in provision of both acute and preventive care (223–227). The principal vaccination access points have included private clinics and dispensaries (pharmacies), charitably supported facilities, the Ministry of Public Health's (MoPH) primary healthcare centre (PHC) network, and Social Development Centres (SDCs) under the auspices of the Ministry of Social Affairs. Implementing partner organisations (national and international NGOs) have historically played an important role in vaccination delivery through technical, material and financial support.

In this study, we focused on system responses to three shocks, the first of which was refugee displacement from neighbouring Syria (further details can be found in the timeline in **Appendix 3**). As of 30th September 2022, there were some 825,000 Syrian refugees residing in Lebanon, down from a peak of just under 1.2m in April 2015. Dynamics of population movement varied over time: the vast majority of those displaced moved across the Lebanese border in a concentrated period from mid-2014 to early 2015. Secondly, from late 2019 onwards, Lebanon was affected by a compound shock, adding effects arising from COVID-19 and an economic crisis to long-term system strains arising from population displacement. There was in addition a large blast in the capital Beirut in August 2020, which destroyed the national vaccine storage warehouse. These shocks have overlapped in complex ways to give rise to new health sector vulnerabilities in Lebanon (206,281). Effects on vaccination delivery are the subject of paper 2 (section 5.3). For vaccination delivery specifically, data on administrative coverage for key antigens indicate large declines in national coverage broadly coinciding with the shocks described above. A key function of this study was to identify system responses to try to address these trends, and to consider ways in which they might have been strengthened.

5.5.3 Methods

5.5.3.1 Design

This was a retrospective, qualitative system dynamics study. Conceptualization was undertaken using a CLD drawing on analysis of transcripts of semi-structured interviews conducted with stakeholders in Lebanon between February 2020 and January 2022.

5.5.3.2 Approach to primary data collection

Study settings and participant recruitment

Interviewees were sampled purposively from stakeholders working at national, regional and local level in Lebanon, including government (the MoPH), donors and agencies supporting the humanitarian response plans (HRPs) in force in the country, implementing partners, and service managers and practitioners involved in front-line primary care (see section 4.3.2 for further details). Regional and facility-level data collection was designed to better understand dynamics affecting service delivery in two governorates in Lebanon, Beirut and Akkar, chosen to reflect the diversity of service delivery challenges in an urban and rural setting respectively, and historical variations in health service access (much lower in Akkar than in Beirut). Table 6 provides a breakdown of interviews conducted, by stakeholder group and timing and their distribution across the analysis (step 1 below) and validation sets (step 3 below) for CLD development.

Table 6. Breakdown of interviews conducted, by stakeholder group and timing – paper 3.

The table also summarises the distribution of interview transcripts across the analysis and validation sets for CLD development.

Stakeholder group	Sub-category	Wave 1 (Feb-Mar 2020)	Wave 2 (Jul 2021-Jan 2022)	Analysis set	Validation set
National	Government	2	1	16	2
	Donors	0	4		
	Agencies	5	5		
	Private sector	0	1		
Regional bodies and implementing partner organisations		1	12	11	2
Local – facility level	Akkar	0	5	6	1
	Beirut	0	2		
Wave total		8	30		
Overall total		38		33	5

Interview design and conduct

38 semi-structured interviews with individual participants were carried out in two waves (February-March 2020, and then July 2021-January 2022). Of these interviews, n=8 were in-person and the remainder remotely via Zoom due to COVID. Interviews gathered information on participant roles within the system, generic structures supporting vaccination delivery, and system behaviours and policy responses that stakeholders identified as linked to the various shocks. Interviews were recorded and transcribed into MS Word. Most interviews were performed in English by the lead author; the small number of interviews that were performed

in Arabic (all at facility level) were jointly conducted by SAI and AN, transcribed, translated into Arabic and then analysed. Interviews were then separated into two sets: one (n=33) for analysis and a second, reserve set (n=5) to enable validation (Figure 22).

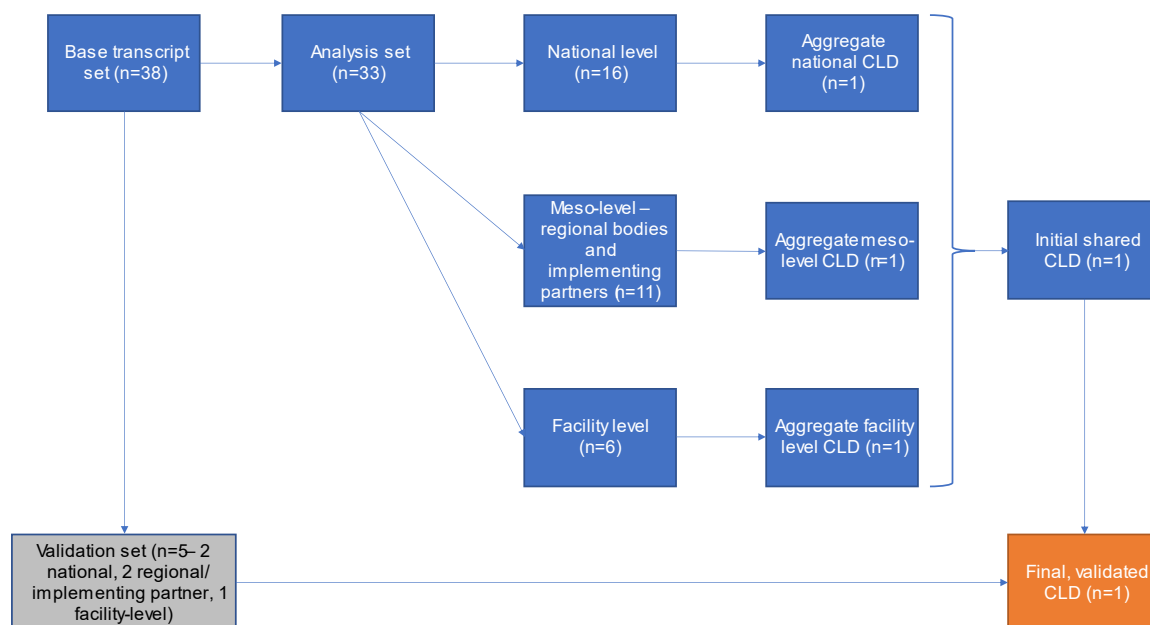


Figure 22. Schematic representation of the process for generating the initial, shared causal loop diagram from the analysis set of interviews.

5.5.3.3 Analysis

The CLD was generated in 3 consecutive steps. First, a CLD was developed for each individual interviewee to represent their mental models of shocks effects on childhood vaccination delivery in Lebanon, and the range of system responses. These were then combined using a stepwise process (outlined below), before a final validation step.

Step 1: generation of individual CLDs

Interview transcripts from the model development set were used for initial conceptualization. Transcripts from the analysis set were coded using purposive text analysis in MS Word, to identify causal language (252,253). Coded segments often talked about experiences, processes or items (e.g., stocks of a particular good) relevant to vaccination delivery system responses to the arrival of refugees from Lebanon, or ongoing efforts to strengthen vaccination delivery across refugee and host community populations in the context of COVID-19 and the economic crisis in Lebanon.

Coded segments were transferred into a separate MS Excel template for Rigorously Interpreted Quotations (RIQs) (253) and marked to identify variables and their causal relationships -- including both the direction of causality (cause to effect) and its polarity (a

positive or negative relationship) according to best practice in CLD diagramming conventions (see **Appendix 4**) (113,117). These were visually mapped using Vensim®, system dynamics diagramming and simulation modelling software tool (254).

Step 2: combining CLDs

CLD combination began by grouping diagrams according to the stakeholder set from which they originated (i.e., national, regional and implementing partners, and facility-level), and then ordered in terms of their complexity (282). Complexity was determined with reference to [i] the number of feedback loops, [ii] the number of delays, [iii] the number of links and [iv] the number of variables in each CLD, in that order. The most complex CLD in each set was used as the “anchor” with which others were then combined sequentially. CLD combination was preceded by a preliminary pruning step in which only delays and feedback loops were retained (255).

Stepwise combination focused on identification of variables, links, delays and loops that were contained in the second CLD but missing from the starting one. These were then added to the anchor. Where two CLDs described the same behaviour but in different ways, the more complex representation was retained because it offered a fuller description of relevant causal chain. Saturation in CLD development over each of these steps was captured by tracking the number of additional variables, links and feedback loops introduced with each additional combination step (282). Another, pruning step was then carried out – this time, to retain only delays and feedback loops incorporating three or more causal links (255).

Step 3: validation and derivation of the finalised CLD

The combined CLD was validated by comparison to n=5 individual CLDs generated from interview transcripts from the validation set, using RIQ analysis (253). Saturation was assessed using saturation curves and CLDs – results are reported in **Appendix 7**. The trajectory of the saturation curves (in terms of plateauing in the number of additional variables, links, delays and feedbacks identified) indicates that saturation was reached through this process.

CLD inspection and identification of leverage points

Once the validation process had been completed, the CLD was analysed to identify the shock responses. Firstly, balancing and reinforcing feedback loops were identified based on the simple rule of thumb set out by Sterman (113), namely that:

- Balancing loops are those in which the number of negative links is odd;
- Reinforcing loops are those in which the number of negative links is even, or in which all links within the loop are positive.

Vaccination delivery system responses to shocks as described in this paper were classified using the absorptive-adaptive-transformative classification outlined in the introduction. Categorisation was based on assessment of the extent to which new system structures were introduced (transformation), new resources mobilised, or existing structures modified (adaptation) as responses to the vulnerabilities identified elsewhere, with reference to the CLD.

5.5.3.4 Ethics

Ethical approval for the research project of which this study forms part was secured in the UK from the London School of Hygiene and Tropical Medicine (ref no 17461), and in Lebanon from the American University of Beirut (ref no SBS-2019-0376).

5.5.4 Results

Figure 15 illustrates, in simplified terms, the balance between vaccination demand and supply dynamics contributing to trends in vaccination coverage over time. The figure also shows key impacts in the system for each of the main shocks described in this analysis: refugee arrivals, COVID-19 and the economic crisis. Effects linked to refugee arrivals were seen mainly on the demand side, while COVID-19 and the economic crisis affected both demand and supply-side dynamics. In the sections that follow, we identify some of the key pathways of system response to these shocks, using the absorption/adaptation/transformation triumvirate outlined above. Where relevant, CLD segments are presented to illustrate key dynamics influencing absorptive, adaptive or transformative responses.

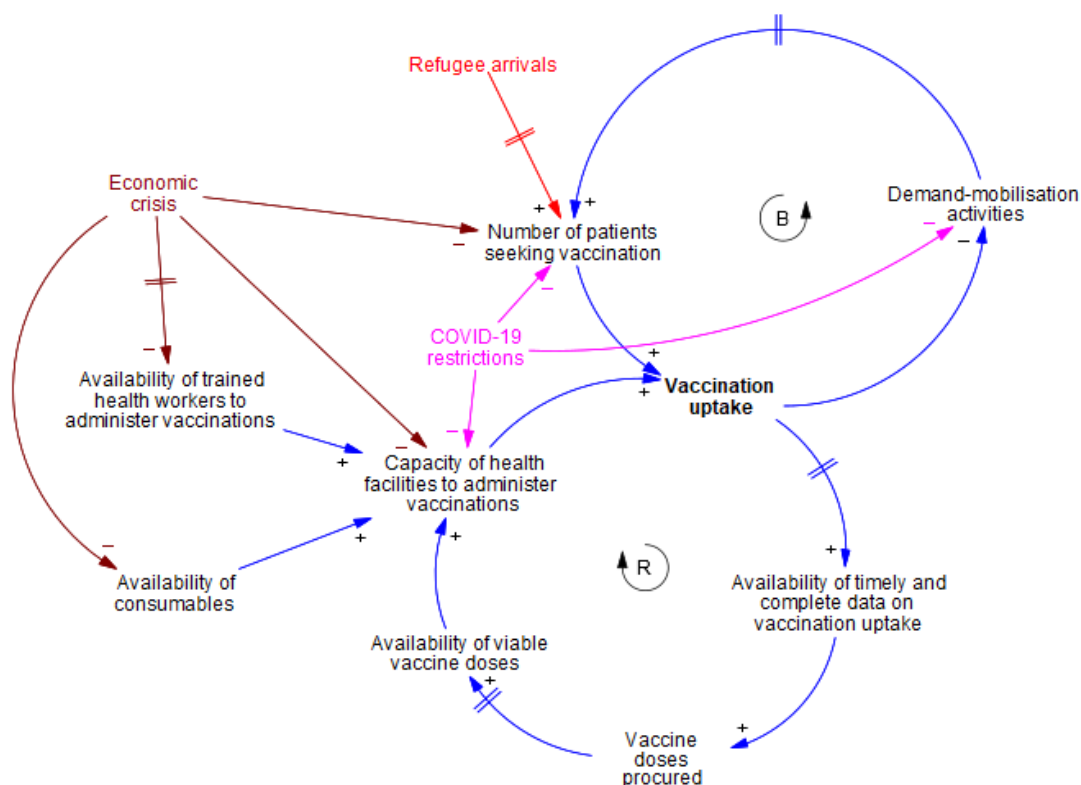


Figure 23. High-level view of the causal loop diagram.

In this visualisation, stable elements of the supply (loop R) and demand (loop B) sides of the vaccination delivery system in Lebanon are represented in simplified form in blue, feeding into the primary outcome (vaccination uptake); dynamics linked to the various shocks are highlighted in red.

A summary of the principal system responses described in the remainder of the results section is given in Table 7. These are classified according to the shock in response to which they were introduced, and the health system building block they primarily targeted. As indicated below, not all of these interventions had the effects originally intended in terms of improvements in childhood vaccination delivery.

Response type System level	Absorptive	Adaptive	Transformative
Macro	<ul style="list-style-type: none"> Focusing infectious disease surveillance activities on COVID-19 [I] ● 	<ul style="list-style-type: none"> Initiation of donor response strategy (LCRP and ERP respectively) [G F] ●●● Policy change to reduce cost of vaccination through PHCs [G F] ● Policy change to promote access via PHCs if distance to the nearest facility was less than 2.5km [S] ● National vaccination campaigns [S] ● Introduction of electronic central vaccine stock management system [M I] ● Direct payment of MoPH staff salaries by donors [F] ● 	<ul style="list-style-type: none"> Policy change to promote nurse-led vaccine delivery via task-shifting [S W] ● Policy change to recruit private clinics to the MoPH's network [S] ●● Introduction of e-record systems [I] ●
Meso	<ul style="list-style-type: none"> Cycling of vaccine stock back to regional (district) level to maintain viability [M] ● 	<ul style="list-style-type: none"> Introduction of border crossing vaccination sites [S] ● Scale-up of MMU use [S] ●● Implementing partner subsidies for vaccination delivery [F] ●● Scale-up of community engagement activities [P] ●●● Introduction of solar fridges [M] ● Change in the currency of implementing partner funding to facilities [F] ● 	<ul style="list-style-type: none"> Introduction of payment-by-results to support task-shifting [F] ●

		<ul style="list-style-type: none"> • Introduction of supplementary payments by implementing partners to improve workforce retention [F W] • 	
Micro	<ul style="list-style-type: none"> • Temporary vaccination clinic closures [S] ••• • Changes to clinic working hours [S] •• • Changes to clinic staffing levels [W] • • Reversion to pen-and-paper clinic records (when e-systems not operational) [I] • • Improved health worker skills and experience through accumulated clinical exposure [W] • 	<ul style="list-style-type: none"> • Staff training (cultural understanding, refugee needs, infection prevention and control and other topics) [W] •• • Introduction of online and social media-based community engagement activities [P] •• • Increased recruitment of entry-level healthcare workers and interns to support service delivery [W] • 	

Table 7. Key system responses identified by the main system level of action, and according to the category of response.

System level of action is given in the table rows; the category of response by the columns. Coloured dots indicate the points at which each response was observed (red dot = refugee crisis response; green dot = COVID-19; blue dot = the economic crisis). Bold letters indicate the kind of intervention implemented, using the WHO health system building blocks (F = financing; G = governance; I = information; M = medicines and technologies; P = people; S = service delivery; W = workforce)

5.5.4.1 System responses to refugee arrivals

Absorptive and adaptive responses

Immediate responses included macro-, meso- and micro-level mobilisation to address what was perceived as a high risk of VPD outbreaks in the context of population movement. At macro-level, adaptive measures included national vaccination campaigns, launched in 2013 and 2014 with increased donor funding support, to address the perceived threat from outbreaks of high-consequence VPDs (polio and measles):

“And there was one time when we did for example pre-emptive vaccination because of the [vaccine derived polio virus outbreak] that happened in Syria. And you know there is a lot of illegal movement that occurs between Lebanon and Syria and thus Lebanon was at risk, and that’s why we had to do pre-emptive vaccination.” [LFS14, implementing partner]

An early policy change concerned the relaxation of rules around access to care for refugees, so that displaced Syrians could access vaccination through publicly supported facilities at nominal cost (capped at LE3,000, equivalent to around US\$2 in 2018 prices). The motivation for this change was to stimulate demand by addressing cost barriers that precluded access through private clinics. However, interviewees noted that imposition of hidden fees (e.g., for consultations) continued to create barriers to access for refugees and other vulnerable populations:

“The product is free, however, it is very important to know that a major challenge that is facing the accessibility of refugees and vulnerable populations to free vaccination is sometimes the hidden fees.” [LFS01, agency representative]

Two additional policy changes were introduced to increase the number of access points. Firstly, vaccination points were established linked to border crossing sites and refugee registration centres to allow for administration of key vaccines (OPV and measles) to displaced Syrians either as they arrived in Lebanon, or as they registered for access to services through UNHCR. Secondly, a strategy of progressive expansion of the MoPH-supported PHC network was introduced, driven by projected need (through implementing partner needs assessments). Facilities in the network received no direct funding from the MoPH, but in exchange for ministry accreditation would receive vaccine doses free of charge (procured via UNICEF) and capacity-building including staff training. A principal condition of membership of the network was to administer vaccines according to the national schedule at the fee rates set out nationally (see above).

Meso-level changes – again predominantly adaptive – also occurred. A key initial response to refugee movement from implementing partners was intensified use of Mobile Medical Units (MMUs) (Figure 24). These had historically been used for outreach to marginalised and remote populations in Lebanon, but the main aim of expansion initially was to reduce the risk of VPD outbreaks by increasing uptake among newly displaced populations. MMUs enabled access for displaced Syrians who tended to settle in rural areas in the North and East of Lebanon where access to fixed-site clinics had historically been more limited (loop B1), but also facilitated referral in to PHCs where those facilities were available locally (loop B2).

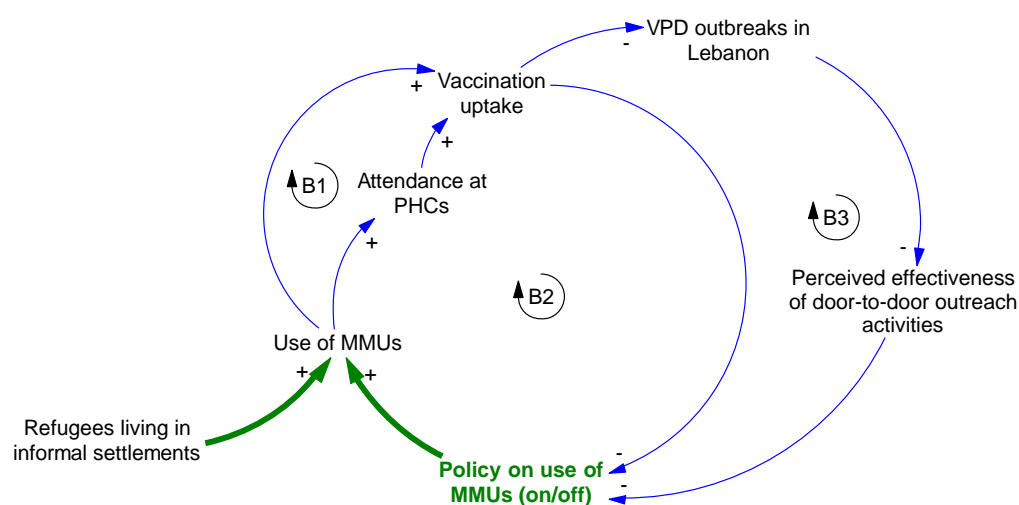


Figure 24. Tensions influencing the use of mobile medical units (MMUs) in Lebanon over time.

Active system response pathways and policies are highlighted in green. Regular system pathways are shown in blue.

Use of MMUs was later scaled back as the result of a combination of concerns. Interviewees highlighted challenges regarding the regulation of quality of care, and a perceived dampening effect on motivation of service users to attend fixed sites. However, there were also concerns that this model was not cost-effective given the emergence of a new and widespread measles outbreak in 2018-19 (loop B3). From 2017 onwards MMU use was progressively scaled back as part of a strategy of encouraging refugees and host communities into fixed-site clinics (loop B2):

“At the beginning of the Syrian influx, there was vaccination at the borders, and there were a lot of campaigns and having mobile units going to the places of Syrian clusters or Syrian groups, and providing them there with vaccines. So they thought...we can stay home and the medical teams will come to us and provide vaccines and we don't need to go, so they were a little bit passive. And then with the Ministry advocacy and coordinated work of NGOs, the mobile units were decreasing, and more work on

referrals to existing primary healthcare centres was done, to make people get used to go to the PHCs.” [LFS12]

Over time, community engagement activities were stepped up to strengthen demand by [i] reinforcing the importance of vaccination as a preventive measure, [ii] offering opportunities to cross-check vaccination records to make sure children were up to date with the national vaccination schedule, [iii] and strengthening household-level knowledge in areas likely to promote a decision to vaccinate – including information on the national schedule, on the actual cost of vaccination to refugees through the PHC network, and the location of the nearest PHC(s). These activities depended on stepped up recruitment of community engagement workers and increases in implementing partner funding – both of which depended on donor funding that took time to mobilise.

Micro-level (within facilities) changes revolved principally around changes to the role of nurses in vaccine administration, as set out in the next section. However, interviewees also noted some absorptive mechanisms promoting system resilience – particularly progressive improvements in workforce skills at facility level as clinic staff became more accustomed to managing increased workload and to better attuned to needs among refugee populations.

Transformative change: task-shifting for vaccination delivery

A key set of policy responses to refugee arrivals concerned task-shifting to nurse-led administration, which introduced new system pathways (Figure 25). These combined a macro-level policy change around health workforce regulation and supporting meso-level policy changes to incentivise a change in delivery behaviour. Interviewees identified two motivations for this change: [i] a desire to reduce the cost of vaccination especially for refugee populations but also for host communities because physicians tended to charge over-the-odds for vaccine administration; and [ii] better workload management given rising demand in a system that previously had relied almost entirely on physician-administered vaccination.

Progress in implementing task-shifting was, however, limited by the availability of financial material resources to support it initially. This ensured that previously dominant loops favouring physician-led administration (loops R1 and R2) continued to drive most vaccination delivery. As Figure 25 shows, physician-administration of vaccines was an important source of revenue for both clinicians, and for PHCs that hosted them. On the one hand, a long-standing preference among host communities for private medical care (including for vaccination) ensured steady revenues for physicians from private vaccination delivery. On the other hand, PHC managers who referred children to physicians privately for vaccine administration could typically expect to receive a cut from the resulting consultation fees.

The introduction of incentive payments to PHCs (via implementing partners) helped to ensure that task-shifting at facility level was finally implemented. It did so by [i] guaranteeing PHC income to offset losses as fewer children were referred to private physicians, [ii] increasing PHC motivation to promote nurse-led administration to patients in the wider context of scepticism especially from host communities (loop R3), [iii] freeing up physician time for more lucrative specialised activities (loop B4), and [iv] by indirectly supporting nurse pay and thereby improving their retention at facility-level. Implementing partners tested various modes of incentivisation, including payments directly to nurses, but these were found to increase the risk of pressure on staff to subsidise other PHC activities (loop B5), so they were phased out in favour of payments to PHC managers to then distribute amongst nursing staff (loop R4).

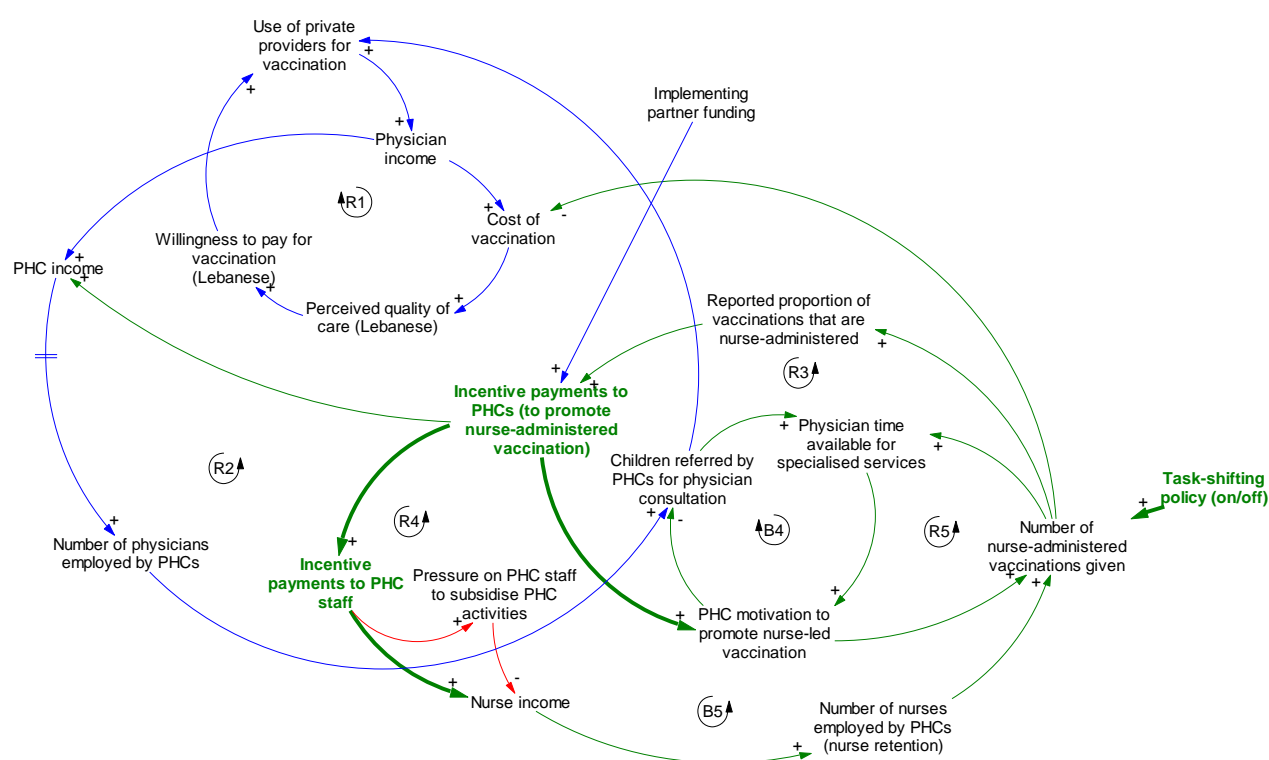


Figure 25. Dynamics linked to the introduction of task-shifting for vaccination delivery in PHCs.

Loops in blue show pathways present prior to the refugee crisis; those in green indicate new structures that emerged as part of the system response. Bold green lines and green variables indicate the principal points of intervention; light green lines indicate downstream effects. Red lines indicate new areas of risk that emerged following the introduction of the interventions.

5.5.4.2 System responses to compound crisis

Absorptive and adaptive responses

Interviewees described a range of responses – primarily absorptive – to COVID-19, many of them operating at micro-level. In the near-term there were absorptive responses to rising perceived risk of contracting infection in facilities, influenced by perceived inability to socially distance, and by health worker concerns about the probability of exposure in a context of rising

caseloads nationally. Measures introduced included local clinic cancellations and reductions in staffing levels to reduce the potential for health worker exposure. However, these reduced access opportunities for patients in the short term, contributing to declines in vaccination uptake. At national level, interviewees highlighted the concentration of resources on COVID-19 surveillance at the expense of monitoring for other VPDs, increasing the potential risk of an undetected VPD outbreak.

Responses elsewhere were adaptive and primarily focused on reinforcing supply and demand through improved risk-management across the system, although lead times to implementation were longer. Stocks of personal protective equipment (PPE) were mobilised and staff training on infection prevention and control introduced to reduce health-worker perceived risk of contracting infection in health facilities. On the demand side, community engagement activities continued but were shifted online or via tools such as WhatsApp. Interviewees noted that the quality of engagement with service users was often poorer as a result of this. There were also adaptations to messaging during this period, to reinforce the importance of vaccination as a preventive service, to emphasise that clinics remained open despite COVID-19 related movement restrictions.

Responses to the economic crisis were similar in nature but generally targeted different pathways within the system (Figure 26). Many adaptive measures focused on maintaining facility capacity to deliver vaccination through additional financial support as currency inflation worsened. These included switching the currency of implementing partner payments from Lebanese currency to US dollars, to offset declining PHC income due to inflation. The goal was to maintain PHC income and therefore capacity to deliver (loops R6 and R7). Some implementing partners also provided direct salary supplements to PHC staff to improve retention (loop R8). Financial support measures did not, during this period, extend to incentives for service users.

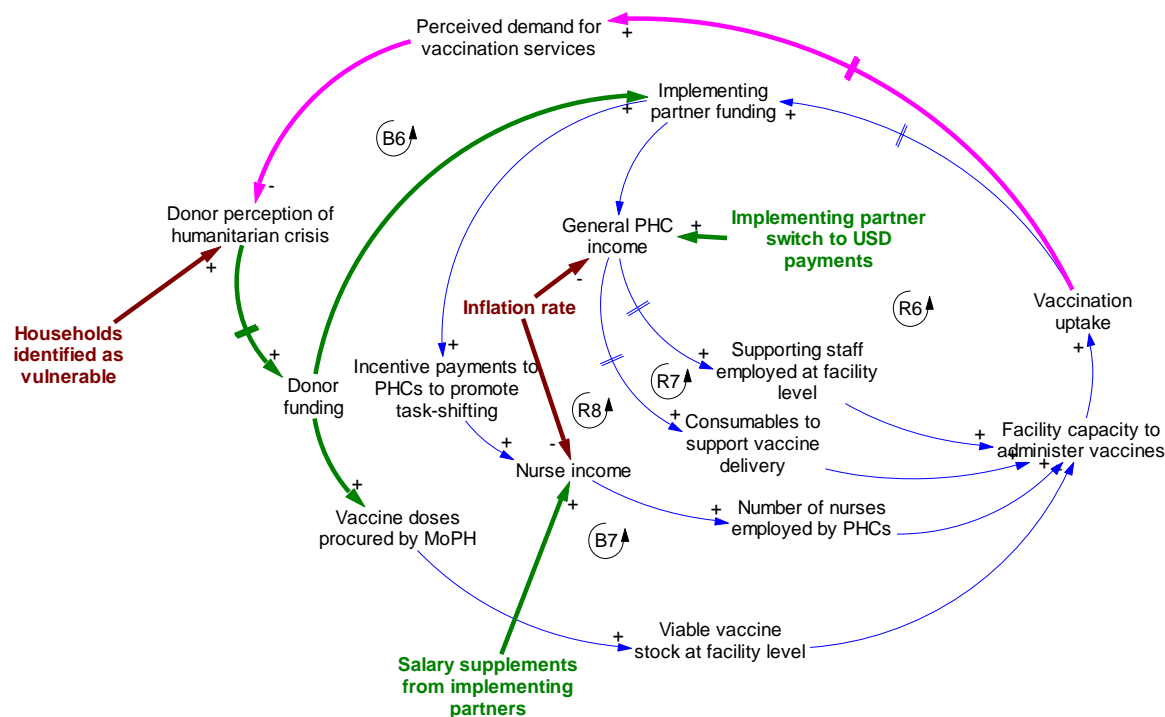


Figure 26. Dynamics linking changing perception of need to mobilisation of donor funding, and downstream adaptive responses within the system.

Lines in bold pink correspond to pathways of impact for COVID-19; lines and text in bold brown correspond to those for the economic crisis. Intervention points are highlighted in bold green text; key response pathways feeding into established system loops are shown using bold green lines.

Mobilisation of donor funding was a key adaptive response to the compound crisis. This was triggered by [i] changes in the COVID-19 caseload, [ii] a collapse in demand for childhood vaccination observed especially during the first COVID-19 lockdown in Lebanon (loop B6), [iii] an emergency appeal following the Beirut blast, and [iv] needs assessments identifying rapid growth in the proportion of households (refugee and host communities alike) identified as vulnerable (loop B6 in Figure 26). Emergency funding following the blast was mostly concentrated around greater Beirut, where damage was greatest. Donor perception of worsening economic conditions as a humanitarian crisis, on the other hand, contributed to strengthening resource support to PHCs nationwide, via implementing partners. It also helped support vaccine procurement to maintain delivery through the PHC network, and – as the following section outlines – recruitment of private sector capacity to support childhood vaccination delivery. However, interviewees highlighted the length of time it took both for declines in vaccination uptake to be identified, and for the implications of the economic crisis for health needs to be recognised. This contributed to delays in funding mobilisation.

Transformative change: integrating private sector delivery capacity

Interviewees described opportunities created by the shocks – in particular the integration of private sector delivery capacity to support childhood vaccination delivery at nominal cost (Figure 27). Although the MoPH had introduced a policy to promote private sector engagement in low-cost vaccination delivery in 2015, this did not attract meaningful private clinic engagement until the economic crisis took hold. Interviewees ascribed this partly to the perceived link between cost and quality of care that ensured host communities continued to take their children to private clinics for vaccination (loop R9), and partly to the lucrative nature of private vaccine administration for physicians (loop R10). Because of this, there was no strong incentive for private clinics to participate in the scheme (loop B8).

However, vaccination uptake through private clinics collapsed in 2021/22. This was the combined result of falling household incomes, and the increasing difficulty these clinics had in obtaining vaccine doses through the open market due to import restrictions. Declining income as a result of this encouraged increasing private clinic participation in the MoPH's scheme. In exchange for free vaccine doses (thereby increasing the stock of viable doses in clinics – loop B9), private clinics were required to drop the cost of vaccination to levels equivalent to those in PHCs, and to report vaccination uptake data to the MoPH.

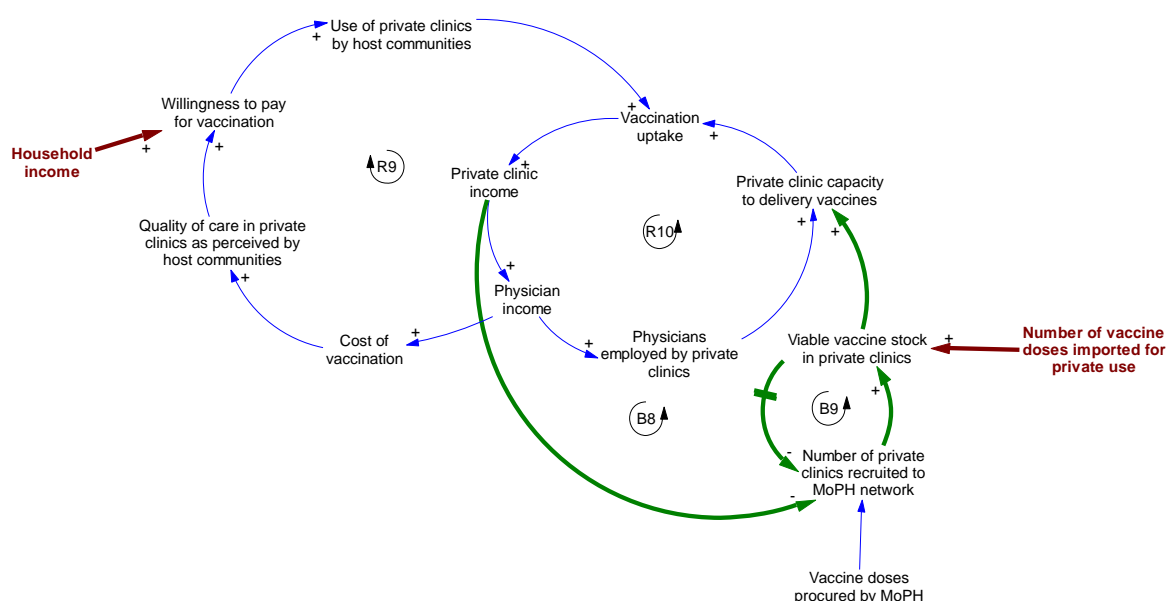


Figure 27. Dynamics linked to private clinic integration into the publicly supported system for delivery of routine antigens at nominal cost to patients.

Points of shock interaction are denoted by brown text and arrows; loops in blue show pathways present prior to the three shocks; lines in bold green indicate new pathways introduced through policy interventions from 2015 onwards. These loops became dominant as the economic crisis took hold.

5.5.4.3 Pathways of interaction across responses to different shocks

Interviewees highlighted areas in which responses to earlier shocks contributed to potentiating the impact of later ones – in three main areas. The first was cold chain integrity (Figure 28), where a key adaptive response to rising demand following the refugee influx, and ongoing insecurity of mains electricity supplies, was the introduction of solar fridges. While this adaptive response improved cold storage capacity in PHCs in the near-term and enhanced facility capacity to delivery vaccinations (loop R11), import restrictions linked to the economic crisis contributed to difficulties in sourcing spare parts for these fridges. Combined with the increasing unreliability of mains electricity supplies, and the scarcity of generator fuel, PHC staff found it harder to guarantee cold chain integrity. Locally, steps were therefore taken to return doses to district-level storage facilities where cold storage was more reliable (loop R12). This in turn increased the risk of facility-level stockouts and reduced the capacity of facilities to respond to local demand in a timely way (loop R13).

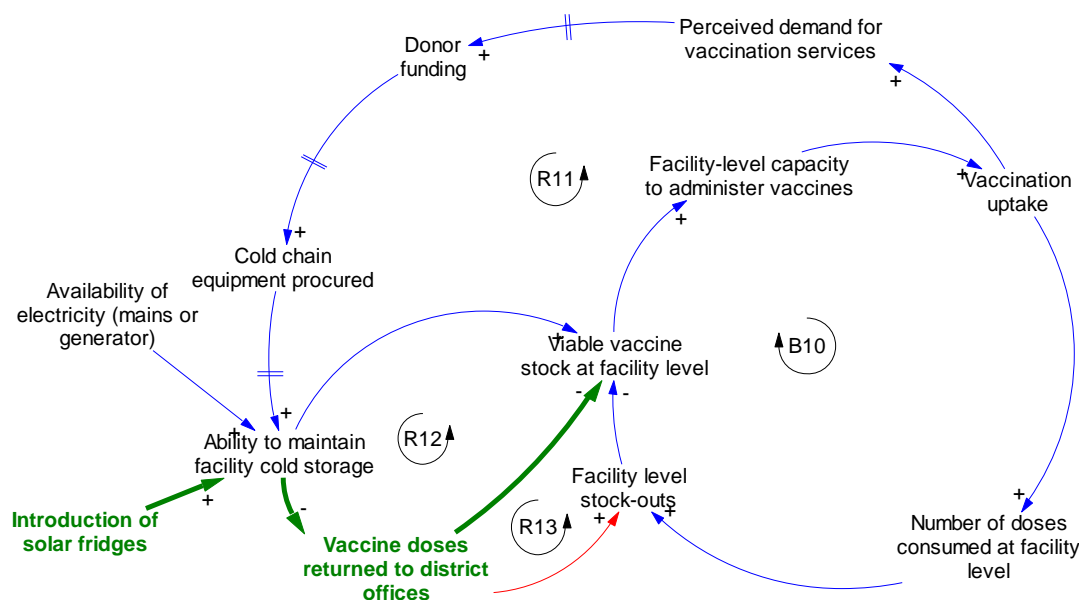


Figure 28. Interactions between early responses and later shocks contributing to vulnerabilities in the cold chain. Dark brown text and lines correspond to lines of threat arising from the economic crisis. Dark green text and lines indicate interventions introduced to support system responses, and red lines indicate new areas of risk linked to those interventions.

Challenges were also noted in operating electronic record systems, originally introduced as a mechanism for improving service efficiency and record completeness following refugee arrivals from Syria. As electricity supplies became more unreliable, facilities sometimes had to revert to paper-and-pen records for which later online reconciliation would be needed to ensure records were complete:

“Because now we are working on an electronic system...and now we have this connection problems...sometimes we are facing some challenges in data collection or in searching, because sometimes to search the name of the child or their parents and to check all the vaccines received by this child at the centre or elsewhere previously, it’s difficult due to the cut or interruption of internet and connections.” [LFS11, government official]

A third point of interaction concerned donor and agency policy regarding financial support for salaries. In 2016 and 2017, a policy decision was taken to provide direct salary support for posts in the MoPH to support the vaccination program (among others), boosting central oversight and program support capacity. However, this policy was later reversed contributing – alongside a general government hiring freeze – to severe staffing shortages:

“You know UNICEF alone supported us with like 100 staff on [district] and central level for two years, 2016, 2017. And they stopped...so now we are in real, real shortage of staff at central and at peripheral level...because all the donors, they don’t want to pay for staffing, they only want to pay for activities, and we cannot do activities without staffing.” [LFS03, government official]

On the other hand, workforce attrition among nursing staff was lower than for physicians as economic conditions worsened. In this sense, task-shifting in vaccination delivery was important in strengthening resilience to a series of shocks – refugee arrivals in the first instance, and then the economic crisis.

5.5.5 Discussion

To our knowledge, this is the first study to apply system dynamics to investigate shock responses to support vaccination delivery system resilience in Lebanon or indeed any other humanitarian setting. We found evidence of a range of responses at different system levels. Almost all of the responses observed were adaptive. They typically operated by strengthening or building on existing system structures through mobilisation of additional financial, human or other resources. The limited number of absorptive responses were seen primarily at micro (facility) level and were principally concerned with short-term workload containment or resource redistribution in response to rising demand, although there was some evidence of improving health workforce skill mix strengthening system resilience over the long-term following refugee arrivals from Syria.

We identified two potentially transformative changes. The first of these was a policy change to bring private clinics under the MoPH’s fold for lower-cost access to vaccines. This policy

was introduced in 2015 but did not result in significant behavioural change until a demand collapse in the private sector occurred in 2021/22 and helped push host communities towards PHCs for vaccination and other health services. The second was the implementation of task-shifting to nurse-led vaccine administration in PHCs. Although neither of these resulted in large-scale goal re-orientation across the system as a whole, both introduced a range of wholly new meso- and micro-level system pathways promoting vaccination delivery that had not previously existed.

System responses were sometimes maladaptive in terms of effects on vaccination uptake. Many of the immediate and early responses to COVID-19 (e.g., reduced clinic working hours, reducing clinic staffing levels) may have helped preserve workforce wellbeing in the short-term and contributed to reducing transmission of infection, but also reduced service access opportunities for patients. The greater focus on absorptive responses to COVID-19 and particularly the economic crisis by comparison with earlier changes following refugee arrivals from Syria – as illustrated in Table 7 – emphasised the extent to which the limits of system resilience were increasingly being reached. Interviewees repeatedly highlighted the growing dependence of the system on donor and implementing partner resources to continue functioning. On the other hand, task-shifting to nurse-led vaccine administration proved a successful mechanism for managing increased service demand across the services by keeping the cost of vaccination down. It was also more durable in the face of the economic crisis than physician-led administration, primarily because emigration routes for nurses were more limited and workforce attrition was lower.

Our findings are novel in showing important points of interaction between system responses, and ways in which some changes implemented to address effects arising from earlier shocks influenced vulnerability to later ones. One example of this was the introduction of imported solar fridges into the cold chain. While this made an important contribution to strengthening cold storage capacity at facility-level following the refugee arrivals, interviewees described increasing difficulties obtaining spare parts for this equipment as import restrictions intensified in 2021/22, increasing cold chain vulnerability at a time when mains- and generator electricity supplies were also increasingly variable. By contrast, the use of task-shifting reinforced long-term system resilience by expanding delivery capacity but also because nurses proved less likely than their physician colleagues to leave their posts or emigrate despite deteriorating economic conditions.

The decentralisation of financing for vaccination delivery – with considerable autonomy for implementing partners to channel funds and other forms of support to facilities – emerged as both a strength and weakness of the system structure. On the one hand, interviewees

highlighted the threat posed by donor fatigue and limited financial resilience within the system to cope with declines in external funding. On the other, the diversity of financing streams proved essential to maintaining vaccination delivery as economic conditions worsened in 2021/22. Implementing partners in particular were able to step in to provide additional financial (sometimes in foreign currency) and technical support in a way that almost certainly would have been impossible for public actors to do in the context of a government hiring freeze and deepening fiscal crisis (206). They could also do so much more quickly than equivalent donor funding could be mobilised.

Findings support those identified in other empirical analyses of health system resilience in humanitarian settings. In particular, our work underscores the multi-modal nature of shock responses (111), the importance of decentralisation for adaptive responses in some areas (110,111,182), and the need for flexible approaches to human resource deployment (111,250). Findings also mirror those from the wider resilience literature in health regarding the importance of collateral (parallel) service delivery pathways. In Lebanon, multiple service delivery modes were used at various stages to bolster uptake, including MMUs, fixed site PHCs, border crossing sites, registration site clinics, and national campaigns among others. The central importance of timely information flows to support situation appraisal is also clear (18). In Lebanon, delays to recognition of critical changes in behaviour (e.g., the time taken to identify changes in service demand, and the time taken for donors to formally recognise unfolding crises) both imposed significant limits on vaccination delivery system responsiveness.

There were several limitations to this analysis. A detailed evaluation of demand-side responses, drawing in service-user perspectives, was not attempted for reasons of practicality and representativeness across populations in Lebanon. This naturally limits what can be said here about community-based resilience strategies. These are likely to have been particularly important during the economic crisis, where anecdotal evidence from interviewees indicates the use of car-pooling strategies to transport children to health facilities as fuel shortages intensified. Secondly, we cannot rule out recall bias affecting reporting of system responses to the refugee influx, given the length of time between peak cross-border movement (in 2013/14) and this analysis (from early 2020 onwards). However, various measures were taken to minimise this including recruiting participants with a spectrum of experience in the system (ranging from a few years to several decades) and inviting participants to focus only on areas where their recollections were strongest.

We highlight a number of important policy implications arising from this analysis. From a service demand perspective, evidence in this study emphasises the extent to which long-term

system resilience depends on delivery through a variety of service delivery models, and continual demand-reinforcement through community engagement (for which multiple strategies were used in Lebanon). It also underscores the need for measures to address multi-systemic risk. Household income proved to be a key determinant of demand and changes here contributed to fundamental shifts in patterns of demand in Lebanon over the study period.

On the supply side, findings in this study emphasise that reactive campaigns are likely to remain a mainstay of efforts to improve vaccination coverage in acute and protracted humanitarian settings, especially because population movement often does not immediately translate into increased demand for preventive services. Secondly, policy changes introduced at macro-level need to be supported by appropriate and suitably financed cascaded measures to ensure on-the-ground implementation. This was evident in the initially slow progression of task-shifting to nurse administration, a policy that proved hard to implement in the face of powerful vested interests without direct incentivisation at meso- and micro-levels. Finally, policies should be designed for the long-term. Although the mutability of on-the-ground conditions in humanitarian settings may make this challenging, we identified examples where insufficient consideration appeared to have been given to long-term risks policies might introduce (e.g. the decision to import solar fridges with difficult to access spare parts in an import-heavy economy), or where sudden policy changes amplified system vulnerabilities (e.g. agency support for civil service salary financing).

5.5.6 Conclusion

This study has outlined a range of mechanisms by which the childhood vaccination delivery system in Lebanon was able to continue functioning despite accumulating vulnerabilities arising from a series of overlapping shocks. Flexibility in financing and human resource allocation proved especially important, but there was evidence of structural transformation in discrete areas of the system that helped ensure continued vaccination delivery. However, by early 2022, the wide-ranging effects of the economic crisis on both demand- and supply-side dynamics appeared close to overwhelming the compensatory effects of absorptive, adaptive and transformational change and highlighted the growing dependence of the system on external support.

5.5.7 Back matter

5.5.7.1 Acknowledgements

The authors offer thanks to all the participants in this work, who gave generously of their time during an extremely challenging period in Lebanon. We also thank officials in the Department

of Primary Care at the Lebanese Ministry of Public Health for supporting the study and in particular for facilitating access to staff in primary care facilities.

5.5.7.2 Funding

The research described in this paper was supported by a Wellcome Trust Clinical Research Fellowship awarded to the lead author (ref no 215654/Z/19/Z).

5.5.7.3 Conflicts of interest

The authors report no conflicts of interest.

5.6 Identifying system vulnerabilities and leverage points

This chapter has shown important, qualitative differences in the way in which sequential shocks in Lebanon affected the vaccination delivery system. Effects linked to the refugee crisis were delayed partly because it took time for refugee arrivals to translate into increased service demand, and partly because it took time to mobilise humanitarian response funding. However, the refugee crisis exposed key supply-side vulnerabilities. These included weaknesses in the cold chain for vaccines, human resource shortfalls and the dominant role of the private sector. Demand-side risks stemmed from the unmanageable cost of vaccination for refugees initially, although these were offset quickly by policy changes. Longer-term, awareness and trust proved especially important determinants of demand. Later shocks were mixed in their effects. The economic crisis gave rise to major demand- and supply-side risks, some of which (in the cold chain for example) concerned pre-existing system vulnerabilities that had only been partially addressed following the refugee influx. Although all of these shocks were macro-level (national) in scope, the most pronounced effects were seen at facility level. CLD segments presented in Paper 2 illustrate how risks cascaded through the vaccination delivery system.

This chapter has also outlined a range of mechanisms by which the childhood vaccination delivery system in Lebanon was able to continue functioning despite accumulating risks arising from a series of overlapping shocks. Flexibility in financing and human resource allocation proved especially important, but there was evidence of structural transformation in discrete areas of the system that helped ensure continued vaccination delivery. However, by early 2022, the wide-ranging effects of the economic crisis on both demand- and supply-side structures appeared close to overwhelming the compensatory effects of absorptive, adaptive and transformational changes outlined in paper 3. Interviewees highlighted the growing dependence of the system on external support to continue functioning.

Drawing on Meadows' classification introduced in Chapter 4, we can identify a range of system leverage points influencing vaccination coverage in the context of these shocks (Table 8):

No	Type of lever	Leverage point	Leverage points identified through the analysis	Example interventions by leverage point
12	Events or patterns of behaviour within the system	Constants or parameters within the system	<ul style="list-style-type: none"> Aggregate financial inputs into the system Number of vaccine doses available to administer through PHC network Number of clinic attendances for vaccination Cost of vaccination to service users (at facility level) 	<ul style="list-style-type: none"> Humanitarian response funding Procurement with UNICEF support to maintain supply at facility level at nominal cost to service users Multiple – spanning vaccination campaigns and SIAs, community engagement work, diversification of service access points, and others Policy change to reduce the cost of vaccination to service users through the PHC network
11		Buffers	<ul style="list-style-type: none"> Human resource availability at central (policy) and facility (doctors, nurses, managers) level Implementing partner funding to facilities 	<ul style="list-style-type: none"> (Temporary) donor funding of staff salaries; change in currency of payments to staff during the economic crisis Regular, contracted funding to maintain services, combined with surge funding to manage near-term demand increases (before donor response funding was mobilised)
10	System structure(s) explaining events and patterns of behaviours	Stock-and-flow structures	<ul style="list-style-type: none"> Physical infrastructure supporting the cold chain to facility level 	<ul style="list-style-type: none"> Introduction of solar fridges; cycling back of vaccine vials to district level when electricity supplies unreliable
9		The length of important time delays	<ul style="list-style-type: none"> Time to identification that a shock was unfolding Time to mobilisation of donor funding Time to distribution of vaccine doses from the national storage warehouse to facility level 	<ul style="list-style-type: none"> N/A N/A Implementation of an electronic stock management system at the central warehouse in Karantina
8		The strength of balancing feedback loops	<ul style="list-style-type: none"> Loop linking PHC crowding to staff willingness to vaccinate and vaccination uptake during COVID-19 	<ul style="list-style-type: none"> Staff training in infection prevention and control; provision of PPE; patient flow measures including

				clinic cancellations or use of fixed appointment times
7		The strength of reinforcing loops	<ul style="list-style-type: none"> Loop linking nurse-led vaccine administration to vaccination uptake 	<ul style="list-style-type: none"> Financial incentives to PHC managers to promote nurse-led vaccination Community engagement work to increase service user trust in nurse-led vaccination
6	Information and controls systems influencing how the system works	The structure of information flows	<ul style="list-style-type: none"> Perception of changing demand for vaccination services at facility level (tracking of vaccination uptake) 	<ul style="list-style-type: none"> Introduction of new e-record systems to document uptake and facilitate identified of missed opportunities for vaccination (MOVs)
5		System rules	N/A	N/A
4		Self-organisation	<ul style="list-style-type: none"> Parallel service pathways to maximise opportunities for access to vaccination 	<ul style="list-style-type: none"> Selective use of MMUs led by implementing partners; opening of border crossing sites
3	Mental models (values, beliefs and assumptions) that govern how the system works	System goals	<ul style="list-style-type: none"> Strategic orientation regarding the inclusion of refugees as a target population for vaccination through the PHC network 	<ul style="list-style-type: none"> Policy change to open PHCs as a common access point for Syrian refugees and host communities, for vaccination at nominal charge
2		The paradigm out of which the system arises	N/A	N/A
1		Transcending paradigms	N/A	N/A

Table 8. Mapping system leverage points identified through the thesis against purposeful interventions implemented to support vaccination delivery in Lebanon since 2012.

Interventions in the final column are exemplars only – for reasons of space this list is indicative rather than comprehensive.

As Table 8 shows, many of the interventions introduced to support system resilience focused on levers lower down Meadows' classification. In contrast to Meadows' assertion that interventions at these points are likely easier to implement but lower impact, interviewees repeatedly emphasised the transformative power of consistent financial inputs into the system, and the importance of stable human resourcing. Chapter 6 extends this analysis to take a closer look at the behaviour of governance systems and consider leverage points relating to governance and legitimacy that primarily concern higher order leverage points.

CHAPTER 6: Governance and health system resilience in contexts of perpetual crisis – insights from Lebanon

6.1 Introduction

As outlined in Chapter 1, empirical research on the contribution of governance factors to health system resilience is limited. This chapter incorporates an empirical paper using qualitative, thematic analysis to interrogate the contribution of governance factors to health system resilience. The emphasis of the paper is on improving understanding of dimensions of governance contributing to, or undermining, long-term ability to maintain threshold levels of vaccination coverage in Lebanon. In doing so, it directly addresses two key areas for further research identified in a recent agenda-setting exercise – namely, relationships between governance models and system resilience; and the question of how and where institutional and other forms of legitimacy may contribute to system resilience (19). The paper draws on an established conceptual framework outlining a series of governance capacities that may contribute to system resilience over the long-term (10). This framework has been widely applied in analyses of health system resilience in general but has not been empirically tested with reference to system governance specifically.

The paper contributes to addressing the third and particularly the fourth research objectives for the project, namely to:

3. Identify specific system pathways or system attributes that may explain how and why the vaccination delivery system in Lebanon responded in the way that it did when affected by each of the shocks addressed in this research project; and
4. Assess the role of governance and institutional legitimacy in contributing to, or undermining, system resilience drawing on empirical evidence on vaccination delivery in Lebanon.

In section 6.4, findings from the analysis are also linked back to Meadows' leverage points framework outlined in Chapter 1.

6.2 Research paper cover sheet – paper 4



London School of Hygiene & Tropical Medicine
Keppel Street, London WC1E 7HT

T: +44 (0)20 7299 4646

F: +44 (0)20 7299 4656

www.lshtm.ac.uk

RESEARCH PAPER COVER SHEET

Please note that a cover sheet must be completed for each research paper included within a thesis.

SECTION A – Student Details

Student ID Number	1806401	Title	Dr
First Name(s)	Sharif Adel		
Surname/Family Name	Ismail		
Thesis Title	Resilience to shocks in national vaccination delivery systems: from analysis of shock effects to resilience-strengthening intervention approaches in Lebanon		
Primary Supervisor	Professor Josephine Borghi		

If the Research Paper has previously been published please complete Section B, if not please move to Section C.

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?*	Choose an item.	Was the work subject to academic peer review?	Choose an item.

*If yes, please attach evidence of retention. If no, or if the work is being included in its published format, please attach evidence of permission from the copyright holder (publisher or other author) to include this work.

SECTION C – Prepared for publication, but not yet published

Where is the work intended to be published?	BMJ Global Health
Please list the paper's authors in the intended authorship order:	Sharif A. Ismail, Fouad M. Fouad, Sadie Bell, Diane Duclos, Josephine Borghi, Karl Blanchet

Stage of publication	Not yet 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. (Attach a further sheet if necessary)	I conceived the study; designed the study with methodological input from SB, JB and KB; collected the data; performed the data analysis with methodological input from SB; drafted the full manuscript; revised the manuscript with supervisory input from JB, KB and SB, and incorporating revisions from all authors.
--	---

SECTION E

Student Signature	Sharif Ismail
Date	02/12/2022

Supervisor Signature	Josephine Borghi
Date	02/12/2022

6.3 Paper 4: Governance and health system resilience in contexts of perpetual crisis – insights from Lebanon

Authors: Sharif A. Ismail^{1§}, Fouad M. Fouad², Sadie Bell¹, Diane Duclos¹, Josephine Borghi¹, Karl Blanchet³

Affiliations

¹ Department of Global Health and Development, London School of Hygiene and Tropical Medicine, UK

² Faculty of Health Sciences, American University of Beirut, Lebanon

³ Geneva Centre of Humanitarian Studies, Faculty of Medicine, University of Geneva, Switzerland

§Corresponding author:

Sharif A. Ismail

Department of Global Health and Development
London School of Hygiene and Tropical Medicine
London WC1H 9SH

E: sharif.ismail@lshtm.ac.uk

Keywords: health system, resilience, governance, legitimacy, vaccination, humanitarian

6.3.1 Abstract

Background

Although the importance of effective governance for health system resilience is widely recognised, empirical research on the role of power relations, legitimacy and other factors in contributing to health system resilience is limited. This paper presents a longitudinal case study on routine vaccination delivery in Lebanon, a country subject to a series of overlapping shocks since 2011. We aimed to identify governance features influencing system resilience to these shocks.

Methods

Qualitative, multi-methods study triangulating findings from three sources: (i) 30 interviews with 27 public vaccination system stakeholders; (ii) minutes from meetings of 28 health sector

working groups from 2013-21; and (iii) relevant strategy and implementation documents. Data were coded in NVivo 12 and analysed using the framework approach, drawing on an existing conceptual framework that posits four main resilience governance capacities: knowledge, interdependence, management of uncertainty and legitimacy.

Results

Two governance capacities emerged as particularly important in explaining vaccination delivery system responses to shocks in Lebanon. Firstly, the legitimacy of macro-level system actors was influenced by path dependencies including historically highly fragmented service delivery arrangements across the public, private and third sectors. Responses to each of the shocks in Lebanon have been characterised by a high degree of *de facto* decentralisation in service delivery. On the other hand, there was a concerted attempt to use the space created by successive shocks to build the legitimacy of the Ministry of Public Health as the key norm-setting institution. Secondly, although there were improvements in situational awareness systems following the refugee influx, changes linked to COVID-19 and the economic crisis reduced the availability of information to actors at all levels regarding routine vaccination delivery and population vulnerability to vaccine-preventable disease.

Conclusion

Distributed governance models can support short-term adaptation to shocks but may undermine critical health system functions if the legitimacy of key actors is not established, and unless robust systems for information exchange between actors and across levels are in place.

6.3.2 Introduction

Research and policy interest in health system resilience has grown rapidly in recent years, particularly during the COVID-19 pandemic (7,24). Resilience is understood here to refer to system capacity to absorb, adapt or transform in response to a shock while maintaining essential structures and functions (10). There is broad acknowledgement that resilience to shocks and chronic stressors depends on the presence of institutions that are perceived as legitimate, and that the nature of system responses to shocks fundamentally depends on power relations within and beyond the health sector (19,119,166). Recent social science work in health and other fields also suggests a link between *polycentric* governance models – in which actors within a system interact and adjust their behaviour in pursuit of collective goals in the absence of central authority – and system resilience (152,285,286).

However, with some exceptions, these theoretical insights have not translated into empirical analyses of health system resilience. The now large literature on health system resilience largely neglects analysis of what role(s) governance may play in explaining system responses to chronic stressors and acute shocks (19,119,269,270). Instead, it emphasises so-called system “hardware”, such as human resource and material inputs and the availability of multiple service pathways (11,12). This has contributed to two powerful critiques of empirical research on health system resilience. Firstly, it is perceived to neglect the importance of power relations in explaining how health systems function (119). Secondly, critics argue that it privileges the *status quo* without sufficient attention to the conditions required to support transitions to more equitable health systems over the long term (166). It is also, however, at odds with trends in the wider socioecological literature on resilience from which health systems work has drawn much theoretical inspiration. In this literature, there has long been recognition of the importance of institutional legitimacy, power and agency in proactively shaping system responses, particularly where transformational changes occur (120,121,152).

Questions concerning the relationship between governance and system resilience are particularly thorny in humanitarian contexts where institutional authority is often more diffuse and contested than in stable settings. Although historically humanitarian actors have tended to operate parallel governance mechanisms in response work, Hilhorst has described a recent transition from what she calls a “classical” to a “resilience” paradigm in support to countries and communities facing humanitarian crises. In this new paradigm, donors, agencies, NGOs and other actors move increasingly to working with and through host country institutions and communities ostensibly to strengthen long-term response capacity (40,287). We must also recognise the practical reality that in many humanitarian settings, crises are not simply acute, time-limited events but chronic, and chronically destabilising, *conditions* in which power relations are constantly re-negotiated (288).

In this paper, we aimed firstly to reduce the empirical deficit in analysis of resilience governance for health systems in humanitarian settings. Secondly, we aimed to evaluate a resilience governance framework, through an exploratory case study on routine childhood vaccination in Lebanon. Lebanon is a middle-income, Middle Eastern country that has experienced a series of acute shocks over the past ten years (see the timeline in **Appendix 3**), now constituting what has been termed a “compound crisis” (198). The emphasis of our study was on improving understanding of dimensions of governance contributing to, or undermining, long-term ability to maintain threshold levels of vaccination coverage in Lebanon.

6.3.3 Methods

6.3.3.1 Theoretical framework

Our conceptual approach drew on a WHO definition of health system governance, and an existing resilience governance framework from Blanchet *et al* (10). Per WHO, “leadership and governance involves ensuring strategic policy frameworks exist and are combined with effective oversight, coalition-building, regulation, attention to system-design and accountability”.²⁰ The resilience governance framework (see Figure 29) sets out three system capacities contributing to resilience – namely absorptive, adaptive and transformative capacity. These are in turn underpinned by four governance capacities: the ability to integrate multiple types of information from multiple sources to develop meaningful *knowledge* about system behaviour; the ability to manage *uncertainty*; the ability to engage with multiple actors across system scales i.e. *interdependence*; and finally the institutional *legitimacy* to norm-set and ensure that those norms are observed.

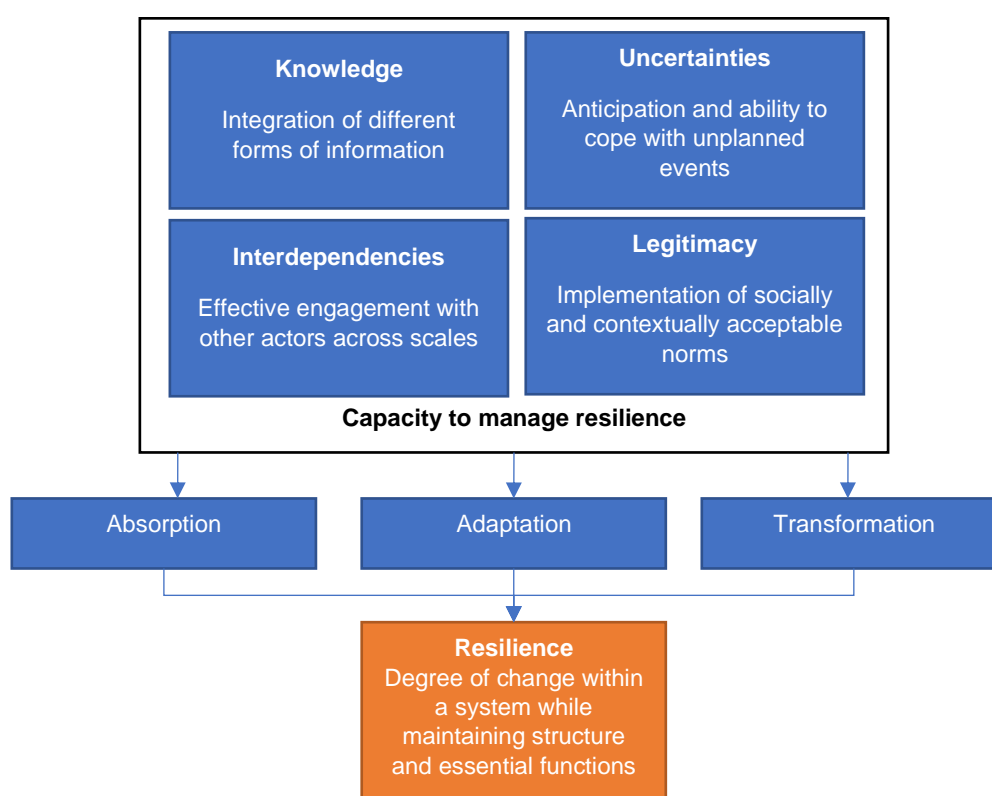


Figure 29. Conceptual framework for resilience governance.

Figure adapted from figure 2 in Blanchet *et al* (10): the original is licensed under CC BY 4.0, which permits unrestricted use, distribution, and reproduction in any medium provided the original work is properly cited – as outlined here: <https://creativecommons.org/licenses/by/4.0/legalcode>.

²⁰ WHO definition: https://www.who.int/health-topics/health-systems-governance#tab=tab_1

In our analysis, we make no explicitly normative judgements about resilience and its contributory factors. Our focus is instead on the overall outcome of resilience in vaccination delivery, and aspects of system governance that may promote or undermine the achievement of that aim over time, in the face of compound crisis.

6.3.3.2 Design and setting for the study

We chose a case study design because this approach is particularly instructive in instances where the boundary between a phenomenon of interest and the context in which it occurs is blurred (245). The setting for the study was Lebanon, a country which currently hosts the largest proportion of refugees of any country in the world following large-scale arrivals from Syria from 2012 onwards. Lebanon has more recently experienced significant disruption arising because of COVID-19, a multi-dimensional political and economic crisis, and a large explosion which destroyed sections of the capital Beirut in August 2020 (206). These shocks together constitute the compound crisis that forms the exposure of interest for this study; a detailed timeline of events during the study period is set out in **Appendix 3**.

International actors (donors, technical agencies and non-governmental organisations or NGOs) have long played an important role in supporting health service delivery in Lebanon (224,225). Since the beginning of the Syria Crisis, however, the international presence has grown markedly and is coordinated through at least three distinct frameworks: the Lebanon Crisis Response Plan (LCRP) (addressing refugee arrivals from Syria), the Emergency Response Plan (ERP) for Lebanon (addressing needs among vulnerable Lebanese following the economic crisis and Beirut blast), and the regional response plan providing support to refugees displaced from Syria (3RP). The LCRP and ERP each contain dedicated health components including support to primary care service provision, working with the MoPH.

Lebanon has historically had comparatively high health spending per capita in regional terms, driven by a large and powerful private sector. Governance and service delivery arrangements for routine vaccination are fragmented. Central oversight is provided by the MoPH, but the vast majority of the Ministry's budget is allocated to funding curative care (289). The MoPH procures routine immunisations through UNICEF. Since 1996 it has also overseen, and provided technical support to, an expanding network of Primary Healthcare Centres (PHCs) through which vaccinations are delivered, but the Ministry does not directly fund these facilities. The private sector has historically been a powerful player in vaccination delivery: until 2019, private providers delivered at least 50% of childhood immunisations. This is in addition to multiple service pathways for refugees depending on their point of origin. These include administration through the PHC network for displaced Syrians, a parallel system for

Palestinian refugees led by the UN Reliefs and Works Agency (UNRWA), and a growing network of informal providers used by non-Lebanese from various countries (235).

Routine childhood vaccination coverage in Lebanon has historically been among the highest in the region, but coverage rates for key antigens declined precipitously both in the immediate aftermath of refugee arrivals from Syria, and more recently following the imposition of lockdowns for COVID-19 control. Analyses published since 2011 have indicated both substantial variation nationwide in the extent of coverage, and significant differences in the effectiveness of delivery (including timeliness) across populations (237–239).

6.3.3.3 Data gathering and management

We drew on three data sources to explore governance dynamics influencing resilience in routine vaccination delivery: (i) key informant interviews; (ii) meeting minutes; and (iii) strategy and operational documents. A total of 30 interviews were conducted with stakeholders working at national or regional level in Lebanon, including government officials, representatives from donors and technical agencies, and representatives from NGOs, and carried out in two waves (February-March 2020; and June 2021-January 2022 6).

Table 9. Breakdown of interviews conducted, by stakeholder group and timing – paper 4.

Stakeholder group	Sub-category	Wave 1 (Feb-Mar 2020)	Wave 2 (Jul 2021-Jan 2022)	Full analysis set
National	Government	2	1	17
	Donors	0	4	
	Agencies	5	4	
	Private sector	0	1	
Regional	Government	0	1	3
	Agencies	0	2	
Implementing partner organisations (span national, regional and local)		1	9	10
Wave total		8	22	
Overall total		30		30

Interviewees were purposively sampled from among these groups. Interviews lasted on average one hour and were semi-structured. We used a topic guide that sought information on (i) the respondents' general perception and experiences of the structure of the vaccination delivery system in Lebanon and its operation, and then (ii) probed specifically around effects – and system responses – linked to the major shocks of interest, including the governance capacities outlined in the theoretical framework in Figure 29. Interviews were predominantly

carried out remotely via Zoom because of COVID-19 restrictions, and were audio recorded. All were conducted in English. Recordings were transcribed into MS Word prior to analysis.

We also drew on 28 sets of written meeting minutes from the national health sector working group (HSWG) for the response to Syrian refugee arrivals, which are publicly available from the UNHCR operational data portal for the Syria Crisis response in Lebanon (207). These meeting minutes spanned HSWG meetings for the period from November 2013-December 2021. Finally, we included strategy and operational documents including (i) MoPH strategies relating to health in general, and EPI vaccination in particular, for the period 2006-21; (ii) annual reports from the PHC network in Lebanon, published by the MoPH; and (iii) agency contingency planning and LCRP operational documents relating to the refugee response, and then from 2020 onwards, relating to the Emergency Response Plan for Lebanon. Documents published in Arabic were translated into English prior to analysis.

Data in all three of the categories described above were uploaded into NVivo 12 for analysis. All material was analysed in February 2022.

6.3.3.4 Analytical approach

Each of the data sources described above were analysed separately using the framework approach (257,258). This pragmatic method combines inductive and deductive coding and was chosen because of the existence of an established conceptual framework after Blanchet *et al* (10) on which we could build. Framework analysis involves five discrete steps: [i] familiarisation with the data, in which an inductive approach is taken to identifying important themes from a subset of data; [ii] identification of a thematic framework – which typically combines themes from the familiarisation stage, with *a priori* themes drawn from prior work or the wider literature; [iii] indexing, in which material from remaining primary data are indexed according to the working framework; [iv] charting, in which material is organised by case or theme; and finally [v] a synthetic “interpretation” step in which key themes and links between them are distilled. Themes identified for each data source were compared with the other two to triangulate findings.

6.3.3.5 Ethics

Ethical approval was secured in the UK from the London School of Hygiene and Tropical Medicine (ref 17461), and in Lebanon from the American University of Beirut (ref SBS-2019-0376).

6.3.4 Results

In this section, we draw out material relating to three principal themes that emerged from data analysis: [i] resilience governance inputs; [ii] actors and networks; and [iii] legitimacy and system oversight. Each theme has a series of corresponding codes and – where relevant – is cross-mapped to resilience capacities from the theoretical framework in the final column in Table 10.

Theme	Codes	Relevant resilience capacities from the governance framework
Resilience governance inputs	The importance of stable financial and human resource inputs	N/A – new
	Perceived prioritisation of routine vaccination delivery	N/A – new
	Effective preparedness and planning for shock-response	Uncertainty
Actors and networks	Tensions between governance fragmentation and central control in routine vaccination delivery	Interdependencies
	Effectiveness of information exchange and networking between actors in the system	Interdependencies; uncertainty; knowledge
Legitimacy and system oversight	Building institutional legitimacy through shock-response	Interdependencies; legitimacy

Table 10. Key themes and codes contributing to the maintenance or improvement of routine vaccination coverage over time in Lebanon, as identified through framework analysis.

6.3.4.1 Resilience governance inputs

Interviewees across stakeholder groups consistently highlighted the importance of inputs in two principal domains – financing and human resources – for effective governance of responses to shocks over time. Prioritisation of vaccination delivery, and proper attention to preparedness and planning also emerged as key factors influencing resilience.

The importance of stable financial and human resource inputs

Financial – and as a result of this, human resource – inputs to vaccination delivery were widely perceived as insufficient to the scale of the demands being placed on the system by sequential shocks. To some extent, this problem predated the Syria Crisis and reflected the historically low priority given to the MoPH in government in budget allocations relative to other ministries:

“We do not receive a big budget from the Ministry of Finance to provide health services. And the budget was mainly going to the hospital admissions and to cancer drugs and only for Lebanese people. So when Syrian refugees came to Lebanon UNHCR was taking charge of those health needs” [LFS11, government official].

As one international agency employee explained, “*why additional things were not done, it was mainly because of financial constraints. The sector was underfunded, and...if a national campaign needed to be implemented at that time, the money was not available*” [LFS01, agency]. Interviews and meeting minutes point to a persistent need for ‘just-in-time’ fund-raising efforts to support critical response activities including campaigns and supplementary immunisation activities (SIAs). Human resource constraints were identified as a critical factor at all levels from national down to facility-level: “*the biggest challenge was for us in health was finding resources. Because in health you know, its staff, its medicine and logistics. If you have these three things you can open a clinic*” [LFS02, agency].

Although the involvement of international actors was key to addressing these shortfalls, instability in the flow of these inputs over time was also perceived as a key constraint to mobilising durable shock-responses. For example, interviewees described a boom-and-bust effect in which a surge in donor funding particularly from 2016-18, helped to cover a large increase in the number of staff directly employed at Ministry level, only for a change in funding policy away from staffing and towards activities soon afterwards. This policy change, combined with a central government hiring freeze to reduce the public sector wage bill in Lebanon in the face of worsening economic conditions, resulted in significant staffing shortages in the MoPH. This had implications for the effectiveness of oversight for vaccination delivery:

“You know UNICEF alone supported us with [around 100 staff on [district] and central level for two years in 2016, 2017. And then they stopped... now we don’t have anybody here... And at the peripheral level, we have only three, our colleagues that are Ministry staff. And also at the [district] level we don’t have anybody now supporting. So now we are in real, real shortage of staff at central and at peripheral level.” [LFS03, government official]

By 2020-21, the effects of the economic crisis had added a new dimension to the human resource retention challenge. Spiralling inflation depressed the value of salaries for government employees, meaning many could no longer afford to continue working in the public sector.

Perceived prioritisation of routine vaccination delivery

Interviewees broadly agreed that childhood vaccination was perceived as a service priority, and that this contributed to resilience in service delivery over time. Routine vaccination coverage for children under 5 was identified as a key target area under the Lebanon Crisis Response Plan (LCRP), and this filtered down to facility level: “*for the Primary Healthcare Centres, [vaccination is] always a priority because it’s a priority for the MoPH and they are*

always pressing on PHCs you have to ensure proper management of the cold chain, you have to ensure the correct quantity, you have to follow-up on all your children" [LFS12, implementing partner]. Particular priority was given to preventive vaccination for polio, which was perceived as a serious health security threat especially in the early years of the Syria crisis. Interviewees emphasised the importance of this in explaining why there had not been any confirmed cases of the disease in Lebanon despite a series of outbreaks in regional neighbours since 2012.

Effective preparedness and planning for shock-response

Chronic financing and staffing shortages undermined central capacity to forward plan and respond effectively to newly emergent challenges. Referring to staffing at the MoPH, one interviewee said *"they are all well-meaning and with great intentions, but I just feel they are all stretched ...they are always in crisis mode, so I don't think they have the ability or the luxury to think of strategic direction forward because they are so stretched due to capacity gaps"* [LFS16, donor]. At meso-level, implementing partner interviewees noted the difficulty of long-range planning in a climate of continuing uncertainty over funding, and steadily reducing project cycle lengths supported by donors: *"my main request...[was] to have multi-year funding, which is more efficient, less use of money, because once you do a multi-year funding, you will have strategic planning for 2-3 years, and you will know better to work, and it's more motivating for the team and more sustainable for the community"* [LFS10, implementing partner].

Short-termism was also linked by some interviewees to political instability and to the terms of donor engagement with the MoPH. For example, rapid ministerial turnover (sometimes every few months, at most every few years) contributed to constant agenda change for the MoPH leadership and undermined capacity to develop long-term strategies to address the challenges the Ministry faced from 2012 onwards: *"every new minister, and we've seen this at the MoPH, starts from scratch, does not really look at a long term plan that the Ministry as an institution has, but rather at his own agenda"* [LFS17, donor].

Although interviewees highlighted activities carried out to increase preparedness for "worst case" events – particularly outbreaks of polio and cholera – their accounts and those from meeting minutes and official documents suggested much of this was reactive rather than proactive. Meeting minutes from 2013, 2014 and 2015 note a series of early planning exercises for responses to suspected polio cases and outbreaks of diarrhoeal disease including cholera (290,291). Several preventive polio vaccination campaigns were carried out in 2013 and 2014 to reduce incident case risk following the emergence of confirmed cases in Syria. However, we found no evidence in national strategies and preparedness documents to indicate prior risk-assessment and planning for conflict, refugee arrivals or sudden surges in

service demand for routine immunisation, despite Lebanon's recent history of conflict and cross-border movement of refugees (292,293). Similarly, there was no discussion of vaccination deployment to displaced populations in the national health strategy preceding the crisis (292). Cross-sectoral contingency planning documents published in the first few years of the Syria Crisis response address vaccination delivery only in very high-level terms (294,295). Finally, although a whole-system strategy to respond to Syrian refugee arrivals in Lebanon was eventually introduced in the form of the LCRP, this was not published until 2015, three years after the first refugees had arrived in-country.

6.3.4.2 Actors and networks

The range of stakeholders involved in routine vaccination delivery in Lebanon has historically been diverse. In this section, we focus on findings addressing stakeholders and network effects underpinning vaccination delivery over time.

Tensions between governance fragmentation and central control in vaccination delivery

Interviewees described a diverse set of delivery arrangements for childhood vaccination across populations in Lebanon. Interviewees noted particular historical limitations to the writ of the MoPH:

“The Ministry has very limited capacity. For example, for vaccines specifically, a lot of support is given to the Ministry...UNICEF are procuring the vaccines...and also recruiting staff to support vaccination, having IT support to create the tracking platform and training of the PHCs on all of that, but in terms of support to PHCs across the country, it has always been through NGOs not the Ministry directly. And also the PHCs are managed either by local NGOs or municipalities or the Ministry directly or the Ministry of Social Affairs...there was always a need for iNGOs and big local NGOs to receive the funds and provide support to both PHCs and the Ministry.” [LFS12, implementing partner]

Some interviewees acknowledged the potentially positive effects of fragmented governance for system resilience, highlighting how implementing partners' financial independence from the MoPH had contributed to preserving service delivery capacity especially as the economic crisis took hold from 2019 onwards. This created space for some of the most important innovations in service delivery in response to refugee arrivals, including the introduction of payment-by-results, variable clinic hours, and the expanded use of mobile medical units for outreach vaccination promotion and delivery. For the economic crisis response, resilience was attributed to external financing streams, but the limitations of this kind of model particularly for vaccination delivery were also emphasised: *“the problem with the use of the term resilience is*

that in Lebanon it is very much linked to the healthcare sector being so loosely governed... when it comes to vaccination this is actually a disadvantage [...] because actually vaccination requires a lot of central planning and coordination” [LFS23, agency].

Under both the LCRP and ERP, health sector coordination was provided through international agencies (UNHCR and WHO), but with involvement from representative NGOs on governance and oversight bodies (296,297), although interviewees all agreed on MoPH’s primacy in governance for vaccination delivery overall. However, there was a tendency towards proliferation of coordination mechanisms, rather than streamlining, due to funding arrangements but also to operational frameworks to which working group members were required to report. Despite the established presence of the LCRP health sector working group, a parallel working group to support the ERP for Lebanon was launched following the Beirut blast in August 2020. This covered financial and other forms of support to primary healthcare delivery through emergency response mechanisms. These two working groups were merged in January 2022 (298).

In addition, the emergence of multiple governance frameworks organised to a greater or lesser extent around specific refugee populations contributed to a perception of exclusion among host communities in Lebanon in the early years of the crisis response, when it came to access to essential services including vaccination:

“When Syrian refugees came to Lebanon UNHCR was taking charge of those health needs, and after the support the PHCs and some health centres provided free services for Syrian refugees. This made a conflict between Lebanese and Syrian populations, because Syrians were covered by UNHCR when Lebanese people have to pay for health services” [LFS11, government official].

A number of interviewees commented on delays in recognising the scale and scope of vulnerability among host communities especially as the economic crisis took hold, and the implications this had had for targeting of health sector response work.

A key point of contestation during the initial phases of the Syria Crisis response was between the MoPH and private clinics delivering vaccinations on a fee-for-service basis. Historically, private clinics in Lebanon operated independently of the MoPH and did not report data on vaccination uptake or adverse events. This trend continued during the Syria Crisis response. Examples included the continuing inability of the MoPH to impose a broadly observed national immunisation schedule, with implications for trust in vaccination delivery:

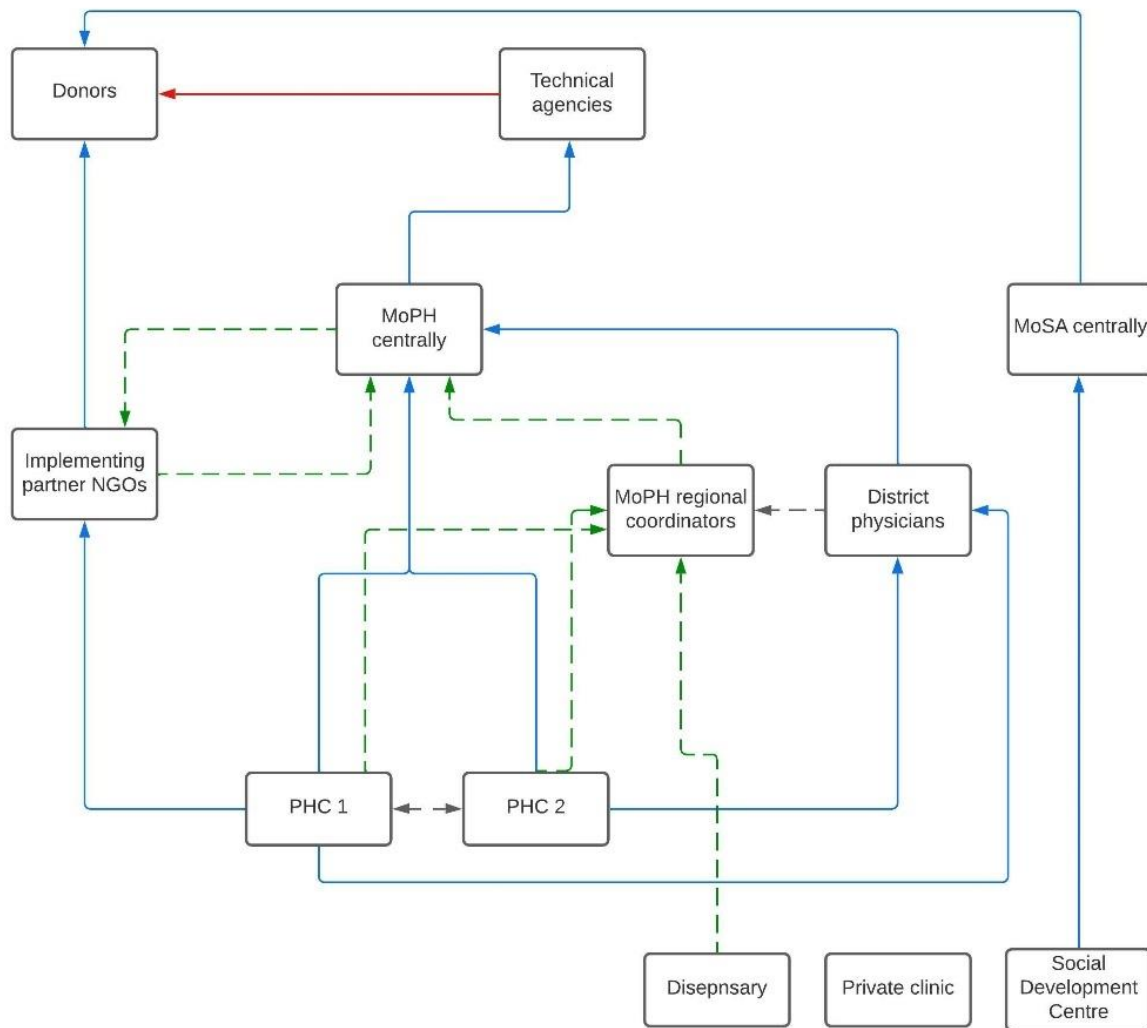
“In Lebanon you do not have a single immunisation schedule...this diversity in schedules...creates an unstable process of immunisation: [if] you look at the immunisation record of some patients, you see that they have taken 4 vaccines, OPV, DTP, polio etc every month. And this is a financial cost for the family, when in fact you can give all these vaccines with a single visit to the physician. It will change the confidence in the vaccination process as a whole” [LFS26, private sector representative].

The economic crisis, however, changed this dynamic. Declining revenues for private clinics as economic conditions worsened helped to spur an increasing number of practitioners to work with the MoPH by signing memoranda of understanding. Under these agreements, private clinics would receive free vaccine doses from the MoPH (procured by UNICEF) on condition that they were administered free of charge to patients, and uptake data were reported to the ministry.

Information exchange and networking

Interviewees emphasised that there had been significant changes in information gathering and exchange across actors involved in routine vaccination delivery since the beginning of the Syria Crisis. However, most of these had been concentrated among those directly involved in the LCRP and/or ERP (Figure 30).

New information exchange channels included, among others, the introduction of two electronic record systems – the Mobile Epi Registry Application (MERA) and PHENICS – in 2018-19 for tracking patient-level vaccination uptake and reporting up to the MoPH from participating facilities (299); and an electronic stock-management system for tracking available vaccine doses nationally. These were in addition to long-standing vaccine-preventable disease (VPD) surveillance systems. These included the active case surveillance system for Acute Flaccid Paralysis run through the Epidemiological Surveillance Unit (ESU) at the MoPH, and occasional, formal analyses of vaccination coverage (cross-sectional, vaccination card-based surveys, but also at least one population level sero-survey). A recurrent theme in interviews, however, was the continuing dependence of the MoPH, donors and other actors on soft data and human intelligence gathered through the MoPH's network of regional coordinators, district physicians, and through health sector coordination meetings.



- Hard copy information flow
- Mixed modalities information flow
- - - → "Soft" information flow - site visits, meetings, informal information exchange

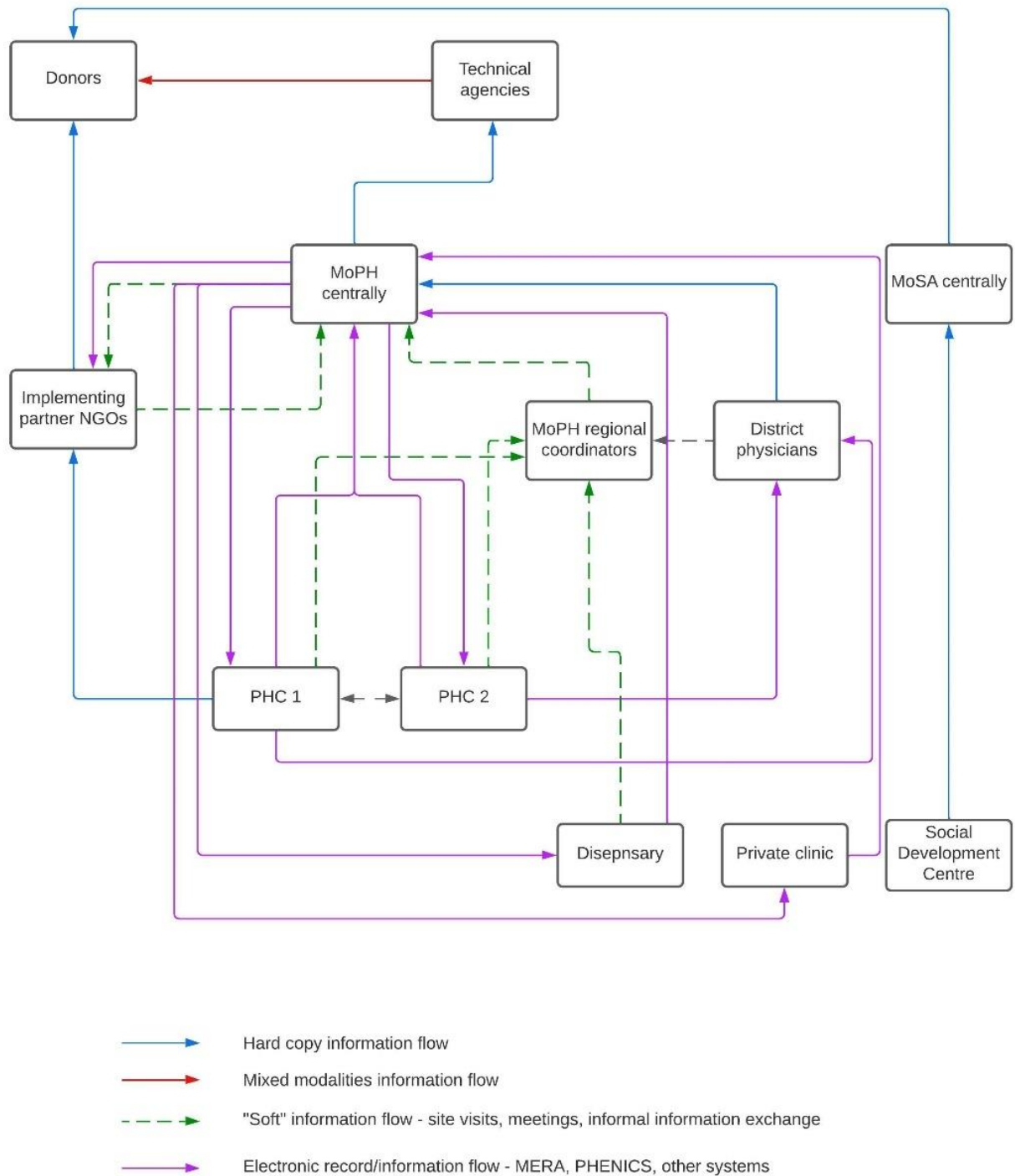


Figure 30. Schematic representations of key information flows within the vaccination delivery system. Two visualisations are presented: at baseline (first panel) in 2012, and at the conclusion of the study in 2021 (second panel). Arrow directions indicate the direction of information flow; arrow colours indicate the types of information moving via each mechanism. Two PHCs are represented to show lines of communication between centres falling under the MoPH's PHC network. Abbreviations: MoPH = Ministry of Public Health; MoSA = Ministry of Social Affairs; NGO = non-governmental organisation; PHC = Primary Healthcare Centre [source for images: author generated]

Strengthened formal and informal networking had important implications for the quality of situational awareness across the system and ability to mobilise resources to support vaccination delivery. At facility level, interviewees described improved tracking of missed opportunities for vaccination because of the introduction of e-record systems centrally coordinated by the MoPH:

“It needed support from the MOPH actually because...the follow-up was great and the circle would be closing with the PHCs we were supporting. But if the child went to a PHC we were not supporting, we would not have access to their data and here we asked for the MOPH to...unify the system and ask those PHCs to report on these children” [LFS12, implementing partner].

Some also described new mechanisms for informal information exchange, some of which had strengthened surge capability. These included a voluntary network initiated through the health sector working group in 2014 that allowed for recruitment of partners working outside vaccination delivery under normal conditions (e.g., on WASH, or education) to mobilise to support community mobilisation during campaigns and supplementary immunisation activities.

Nevertheless, in 2021 a large majority of the dispensaries and the private clinics in which over half of routine vaccination doses nationally were given, continued to operate outside these systems. Among other implications, this meant that vaccination coverage estimation could only ever be approximate:

“60-70% of Lebanese do go to the private sector but we have not one data from the private sector. So I can only speak about children going to the public. I have no idea about all these children going to the private. I also have no idea about the quantity of vaccines procured privately by the private sector” [LFS05, agency].

In addition, pressures linked to the economic situation and COVID-19 were beginning to roll-back some of the progress that had been made. Nationally, demand for detailed COVID-19 data prompted a re-prioritisation of ESU resources towards pandemic response and away from VPD surveillance. Interviewees expressed alarm at the implications for monitoring high-risk VPDs, and ability to rapidly mobilise vaccination-based responses if they arose: *“during COVID all the ESU systems and the active surveillance were focusing more on COVID, so the active surveillance was not properly done so we don’t know if there were really AFP cases that were not properly detected”* [LFS11, government official]. Routine VPD reporting returned as a consistent feature of health sector working group meetings only from May 2021 onwards (300). Interviewees also described challenges to electronic data entry at facility level because of electricity shortages, and growing difficulties in accessing service data:

For a while because we were trying to go paperless so we can have an accurate data and the data will all be on the servers of the Ministry and we can rely on this to calculate the drop-out rate and the vaccination service provision, but now with the interruption of the internet connection, we have a lot of problems. Because we...took a lot of time to shift from paper to electronic system, but now when we are doing well...instead of improving and upgrading we will go down to a paper system.” [LFS11, government official]

Finally, a number of interviewees pointed out areas in which information join-up remained incomplete. One example was vaccine dose usage: *“where there is a gap is between the central warehouse and the primary health centres. So that is a bit of manual process, and there is often a disconnect in terms of what is being used at the primary health centres, the consumption at the primary health centres and what has been dispatched for example”* [LFS04, agency]. Some were linked to lack of robust population denominators, and the inability to properly disaggregate vaccination delivery data between key population groups: *“we have no denominators. The last census for Lebanon was 1932. Since then we are estimating the population, and we have no idea when we say 80%, I mean I can tell you 1,287,000 vaccinations injected. What does that mean in terms of coverage? I also have no disaggregated numbers. I have total PCV injected is XX in January, but I can’t tell you how many Lebanese, how many Syrians.”* [LFS05, agency].

6.3.4.3 Legitimacy and system oversight

In this section, we review results relating to the perceived legitimacy of institutions and publicly supported providers and the implications of this for resilience in routine vaccination delivery in Lebanon.

Building institutional legitimacy through shock-response

Earlier results have noted positioning of the MoPH as the key domestic partner for donor support to the Syria Crisis response and more recent Emergency Response Plan for Lebanon. Interview evidence also demonstrated how successive shocks in Lebanon – to some extent the Syria Crisis response but particularly the economic crisis – had been exploited to try to bolster the legitimacy of the MoPH as central norm-setting institution for vaccination delivery.

One aspect of this concerned the expansion of the MoPH’s domain of influence over primary care providers through the PHC network. Here, access to resources through donor support and the Syria Crisis response including free vaccine doses, chronic disease medications and capacity-building interventions was provided in exchange for an agreement to administer vaccinations to patients free of charge, and to report uptake data:

“The Ministry has monitoring and evaluation power over these centres, coordinators, regional coordinators visit these centres on routine basis. They provide on the job support, training to nurses there, they also provide formal training sometimes there, they also provide formal training there sometimes, the Ministry provide formal training to these staff and support as well. So this is how the Ministry tried to increase the governance” [LFS01, agency].

MoPH support was provided in-kind, with funding coming instead from implementing partner NGOs, charitable and/or municipal sources. However, expansion of the network over time was substantial – rising from 138 participating facilities in 2010 to over 250 centres by 2020 (301,302).

A second aspect concerned private sector engagement. The MoPH had tried consistently to improve private sector engagement from 2015 onwards when a Ministry circular was issued calling for private clinics to partner with them to provide vaccination free of charge, in exchange for free supplies of vaccine doses. This initiative enjoyed strong support from agency partners who saw an opportunity to re-shape patterns of vaccination delivery for greater long-term resilience by co-opting private providers:

“If we bring massive public free immunisation, we are killing the private system. So where we are now is really trying to work with the paediatricians, that from the time of the campaign they are with us, they vaccinate the children, that eventually we give them the vaccines and they report to the Ministry of Health” [LFS05, agency].

However, these engagement attempts initially yielded limited results with only a handful of partnership contracts signed by early 2022.

The economic crisis from late 2019 onwards appeared to turn the power dynamic between the MoPH and private providers, for three reasons. Firstly, escalating import costs that meant private clinics were no longer able to purchase vaccine doses as usual. Secondly, private clinics could no longer guarantee cold storage space because of electricity cuts. And thirdly, collapsing household incomes meant that many Lebanese who would previously have sought vaccination through private clinics could no longer afford to do so. In this climate, private providers increasingly saw partnership with the MoPH for access to free vaccine doses as necessary to maintain patient (client) relationships: *“now we are resorting to making contracts with the MoPH as private sector to get vaccines from them for free, and deliver vaccines for free for our clients...this is the only way to keep on with immunisation” [LFS26, private sector representative].*

6.3.5 Discussion

6.3.5.1 Summary of main findings

Drawing on in-depth fieldwork in Lebanon, this analysis has underscored advantages and drawbacks for system resilience arising from fragmented governance models that have been identified elsewhere (152,168,170,285,303). A high degree of pre-crisis governance fragmentation in vaccination delivery in Lebanon, and limited attention to preparedness or planning for large-scale refugee movement meant that a set of spaces existed for donors, technical agencies and implementing partner NGOs to innovate and to support scale-up of services. This helped to meet rising demand linked to Syrian refugee arrivals initially, and the economic crisis later on. It supported short-range, and in many cases adaptive responses to each of the shocks that formed the compound crisis. However, governance fragmentation also contributed to challenges of coordination and tracking in a service area (vaccination delivery) where there is a normative tendency to strong, hierarchical control. This tension was exacerbated by the historically limited authority of the MoPH, and the slow mobilisation of system-level responses to refugee arrivals from Syria in what has been termed elsewhere as a deliberate “policy of no-policy” (304).

There were important changes in networking and particularly information exchange over time that suggested the beginnings of a transition to polycentrism. Information flows that were initially primarily upward and often *ad hoc* became more integrated and formalised across the system in the period up to 2019. However, difficulties in sense-making persisted because of the lack of join-up between information systems, and as the economic crisis took hold electronic information exchange became increasingly vulnerable. Adaptive, perhaps even transformative, changes in this domain were also limited in their reach, excluding large parts of the private sector, dispensaries and a network of health centres operated by the Ministry of Social Affairs, for example. Finally, the practical autonomy of many key actors – most obviously the MoPH – continued to be constrained by funding and human resource shortages. Interviewees repeatedly emphasised system dependency on external funding and technical support.

A striking feature of the response to successive shocks in Lebanon was the strategic effort to strengthen the MoPH’s legitimacy as a norm-setter and coordinating focus for vaccination delivery. This is in contrast to critiques of resilience-promotion that have framed it as cover for a ‘neoliberal’ impulse to roll back the state (40,166,305). This effort actively exploited the operating space created by system shocks. Initially, it was tied to resources available only because of the Syria Crisis response but it took advantage particularly of changing power dynamics between private providers and the MoPH as demand for private services collapsed in the face of economic crisis. By early 2022, these activities had resulted in a large expansion

of the number of PHCs within the network and signalled a potentially transformative change in the accessibility of childhood vaccination for host communities and refugees alike. However, the model of institutional legitimacy on which this change was primarily transactional. The expansion of the MoPH's role in oversight and coordination of vaccination delivery was built on the promise of access to resources for partner organisations (in turn dependent on donor funding), as much as on the order-based or procedural forms of legitimacy identified elsewhere in the resilience literature (e.g. 11). There is an important policy question concerning the long-term sustainability of this kind of strategy in Lebanon as in other humanitarian settings where the legitimacy of state institutions is in question.

In this case study, shocks reinforced some existing power dynamics – in particular the central roles of donors, technical agencies and implementing partners in vaccination delivery. They also, however, contributed to changing others although these effects were often contingent on the nature of the shock. This was most evident in the engagement of private providers. This effort had limited success until 2019; it was not until the economic crisis undercut private providers' ability to purchase vaccine doses, and precipitated a demand shift towards the PHC network, that this balance of power appreciably changed.

Above all, our findings emphasise the critical importance of inputs – financing, human resources and preparedness/planning – to effective resilience governance in systems facing crisis. Interviewees repeatedly emphasised the limitations imposed by funding and human resource shortages on ability to take a long-term view of vaccination delivery needs, as highlighted elsewhere (281). They also, however, noted the resilience-promoting effects of widespread consensus on the importance of routine childhood vaccination as an essential service.

6.3.5.2 Strengths and limitations

To the best of our knowledge, this is the first study to empirically evaluate the framework developed by Blanchet *et al* as a means for understanding the role of governance in health system resilience at macro-level; previous work has focused on bottom-up governance approaches in the context of climatic shocks (270). Findings reported here suggest that while the conceptual framework in Figure 29 accounted well for dynamics influencing governance responses to shocks in Lebanon, potential modifications might account for the upstream role of critical inputs in determining those responses.

Limitations included the fact that interviews were carried out some years after the first refugee arrivals from Syria, increasing the risk of recall bias. We addressed this by triangulating using additional sources including meeting minutes and strategy and implementation reports. As in all purposively sampled qualitative work, our intention was to gather a diverse range of views

but it is possible that some themes were missed because of our sampling approach: we did not interview service users, so material on effects of community-level dynamics on system governance did not form part of our analysis. Finally, some potentially relevant topics – in particular the role of corruption – were not addressed in detail by interviewees despite probing, possibly because remote interviewing (during the pandemic) limited opportunities for trust-building that would have been available if a face-to-face approach had been used.

Specific limitations applied to the use of meeting minutes from the health sector working group. Firstly, the meeting minute record was not complete and notes from some discussions, especially in the early years of the Syria Crisis, were missing. Secondly, meeting minutes were generally brief and although all included attendee lists, the absence of contextual notes limited the extent to which power relations between key actors “in the room” could be discerned. Finally, there may have been dynamics relating to informal or less visible actors influencing governance systems which would not have been captured.

6.3.5.3 Implications for policy

Four broader policy implications arise from our analysis. First, effective governance for resilience to shocks depends, at a minimum, on stability in funding and human resource inputs, and usually on an ability to rapidly mobilise increased resources. Both of these areas have potential for operationalisation as measures of system resilience. For donor organisations, an important implication is that short funding cycles undermine resilience at all levels by promoting short-termism and reducing mental and physical space for innovation and strategic planning.

Second, shocks can provide moments of opportunity for shifting health sector power-relations in directions that can promote universal health coverage – provided these are recognised. In Lebanon, the groundwork for expanded publicly supported primary healthcare provision had been laid long before a profound economic crisis helped create the conditions for a transition away from private provider dominance. The scale of this shift in patient behaviour linked to the economic crisis did not appear to have been anticipated in advance.

Third, transactional approaches may offer viable short-term strategies for building legitimacy of key health institutions, with international support, in humanitarian settings. However, careful consideration will be needed to the sequencing of transition to legitimacy-building via other means including consent and improved transparency, for long-term sustainability. Finally, trade-offs matter: for vertically oriented services such as vaccination delivery there is a natural tension between the impulse to distributed governance to allow space for innovation in response to crisis, and the need for strong oversight particularly in controlling high-risk VPDs such as poliomyelitis.

6.3.5.4 Implications for future research

Findings from this study suggest rich possibilities for future work on health system governance and resilience. Comparative work will be important in empirically testing the consensus in fields outside health that polycentric models improve system resilience, by looking at other service areas within and outside health (121,152,286). Further work is also needed to understand the impact of trade-offs between distributed governance and central control in critical health service domains. From a methodological perspective, although this study highlighted the central importance of networking and interdependencies in explaining the nature of system responses over time, there are natural limits to what may reasonably be inferred regarding either of these using the framework analysis approach employed here. Future work should explore the potential of network analysis for research purposes, and to support resilience assessment and measurement. Finally, empirical evaluation of a resilience governance conceptual framework in Lebanon showed that it offers good explanatory power in trying to understand system responses. However, it also showed that there is scope for adapting it to include critical inputs – particularly in the domains of financing and human resources – without which effective governance responses do not seem to be possible.

6.3.6 Endnotes

6.3.6.1 Acknowledgements

The authors offer thanks to all the participants in this work, who gave generously of their time during an extremely challenging period in Lebanon. We also thank officials in the Department of Primary Care at the Lebanese Ministry of Public Health for supporting the study and in particular for facilitating access to staff in primary care facilities.

6.3.6.2 Conflicts of interest

The authors report no conflicts of interest.

6.3.6.3 Funding

The research described in this paper was supported by a Wellcome Trust Clinical Research Fellowship awarded to the lead author (ref no 215654/Z/19/Z).

6.4 Identifying system vulnerabilities and leverage points

This chapter has shown how governance systems for vaccination delivery in Lebanon evolved in response to sequential shocks. Responses to each of the shocks in Lebanon were characterised by a high degree of *de facto* decentralisation in service delivery. This stemmed partly from the historically fragmented governance of the health sector and limited norm-

setting legitimacy of the MoPH. However, there was a concerted attempt – through shock responses – to build the legitimacy of the MoPH, particularly in the space for change created by the economic crisis. Secondly, although there were important improvements in situational awareness systems following the refugee influx, changes linked to COVID-19 and the economic crisis reduced the availability of critical information to actors at all levels regarding routine vaccination delivery and population vulnerability to vaccine-preventable disease.

Returning to Meadows' leverage points framework as described in Chapters 4 and 5, new or reinforced insights linked to the analysis presented in this chapter are given in red in Table 11 (overleaf). The analysis presented in this chapter shows how changes to information flows, and the rules governing the vaccination system (leverage points 5 and 6 in the table) helped to support system responses to shocks in Lebanon. They also show how higher order levers concerning system goals, and conversely lower order ones concerned with system inputs, also influenced system capability to deliver vaccinations across population groups. From a system goals perspective, interviewees emphasised the extent to which vaccination delivery was identified as a policy priority from an early stage of the response to the Syria crisis, and importance of this in ensuring mobilisation of funding and technical support.

However, changes implemented through these leverage points were vulnerable. Attempts to increase the norm-setting capability of the MoPH, for example, were predicated on continued donor support (in the form of procurement of vaccines doses) and stability in financing flows and human resource levels. Both became increasing sources of vulnerability during the economic crisis, although the effect of this was partly offset by collapsing demand in the private sector (see chapter 5). This reinforces the view that leverage points in Meadows' framework should not be viewed in isolation: they are meaningful only within a broader system structure. Relatedly, these findings suggest that successful action in one domain is often contingent on appropriate support through leverage points elsewhere in the system.

No	Type of lever	Leverage point	Leverage points identified through the analysis	Example interventions by leverage point
12	Events or patterns of behaviour within the system	Constants or parameters within the system	<ul style="list-style-type: none"> Aggregate financial inputs into the system Number of vaccine doses available to administer through PHC network Number of clinic attendances for vaccination Cost of vaccination to service users (at facility level) 	<ul style="list-style-type: none"> Humanitarian response funding Procurement with UNICEF support to maintain supply at facility level at nominal cost to service users Multiple – spanning vaccination campaigns and SIAs, community engagement work, diversification of service access points, and others Policy change to reduce the cost of vaccination to service users through the PHC network
11		Buffers	<ul style="list-style-type: none"> Human resource availability at central (policy) and facility (doctors, nurses, managers) level Implementing partner funding to facilities 	<ul style="list-style-type: none"> (Temporary) donor funding of staff salaries; change in currency of payments to staff during the economic crisis Regular, contracted funding to maintain services, combined with surge funding to manage near-term demand increases (before donor response funding was mobilised)
10	System structure(s) explaining events and patterns of behaviours	Stock-and-flow structures	<ul style="list-style-type: none"> Physical infrastructure supporting the cold chain to facility level 	<ul style="list-style-type: none"> Introduction of solar fridges; cycling back of vaccine vials to district level when electricity supplies unreliable
9		The length of important time delays	<ul style="list-style-type: none"> Time to identification that a shock was unfolding Time to mobilisation of donor funding Time to distribution of vaccine doses from the national storage warehouse to facility level 	<ul style="list-style-type: none"> N/A N/A Implementation of an electronic stock management system at the central warehouse in Karantina
8		The strength of balancing feedback loops	<ul style="list-style-type: none"> Loop linking PHC crowding to staff willingness to vaccinate and vaccination uptake during COVID-19 	<ul style="list-style-type: none"> Staff training in infection prevention and control; provision of PPE; patient flow measures including

				clinic cancellations or use of fixed appointment times
7		The strength of reinforcing loops	<ul style="list-style-type: none"> Loop linking nurse-led administration vaccine administration to vaccination uptake 	<ul style="list-style-type: none"> Financial incentives to PHC managers to promote nurse-led vaccination Community engagement work to increase service user trust in nurse-led vaccination
6	Information and controls systems influencing how the system works	The structure of information flows	<ul style="list-style-type: none"> Perception of changing demand for vaccination services at facility level (tracking of vaccination uptake) 	<ul style="list-style-type: none"> Introduction of new e-record systems to document uptake and facilitate identified of MOVs
5		System rules	<ul style="list-style-type: none"> Norm-setting capability (legitimacy) of MoPH 	<ul style="list-style-type: none"> Financial and technical support from donors and agencies to procure vaccines for the EPI program Contracts between the MoPH and private providers to provide vaccines at nominal cost and report uptake in exchange for free doses
4		Self-organisation	<ul style="list-style-type: none"> Parallel service pathways to maximise opportunities for access to vaccination 	<ul style="list-style-type: none"> Selective use of MMUs, opening of border crossing sites
3	Mental models (values, beliefs and assumptions) that govern how the system works	System goals	<ul style="list-style-type: none"> Importance attached to vaccination vis-à-vis other strategic priorities for health actors Strategic orientation regarding the inclusion of refugees as a target population for vaccination through the PHC network 	<ul style="list-style-type: none"> LCRP and MoPH strategy documents underscoring the prioritisation of vaccination Policy change to open PHCs as a common access point for Syrian refugees and host communities, for vaccination at nominal charge
2		The paradigm out of which the system arises	N/A	N/A
1		Transcending paradigms	N/A	N/A

Table 11. Mapping system leverage points identified through the thesis against purposeful interventions implemented to support vaccination delivery in Lebanon since 2012.

For reasons of space this table is indicative rather than comprehensive. New leverage points highlighted by this study are given in red text.

CHAPTER 7: Strengthening vaccination delivery system resilience in the context of protracted humanitarian crisis – a realist-informed, systematic review

7.1 Introduction: background to the review

The CLDs presented in Chapter 5 and the qualitative analysis in Chapter 6 highlight a series of system bottlenecks contributing to ongoing challenges in maintaining routine vaccination coverage in Lebanon. These bottlenecks acted as constraints to system performance but were conversely also potential leverage points for action. From a supply perspective, there were readily identifiable, macro-level delays in, for example, crisis recognition by key actors (including government, but perhaps especially humanitarian actors) with implications for speed of mobilisation of funding and other resources for response. These contributed to time delays in mobilisation of funding and resources down to facility level. At micro-level, problems included a lack of, and delays in recruitment of, qualified nurses to administer vaccinations. Interviewees also highlighted a need to prioritise preservation of health worker salaries especially in the face of worsening economic conditions on the ground in Lebanon.

From a demand perspective, the need for robust and ongoing community engagement emerged as a strong theme. A series of loops in the CLD point to low baseline confidence in public facilities especially among host communities. This underscored the importance of ongoing engagement with this population to encourage attendance at PHCs for vaccination, as well as the need to convince them of the quality of vaccination administered in these centres, by nurses (following task shifting).

Each of these time delays and aspects of system behaviour are, theoretically, amenable to intervention, to further enhance vaccination system resilience and ultimately vaccination coverage. This chapter considers policy and practice strategies that may be effective in addressing bottlenecks in the interests of long-term system resilience, drawing on evidence from the international literature. In doing so, it addresses the final research objective, namely to identify evidence-based interventions to strengthen vaccination delivery system resilience to shocks, and their potential applicability in the Lebanese context. Here, I present the results of a realist-informed systematic review of existing literature on system-level interventions to strengthen resilience in vaccination delivery in crisis-affected settings, focusing particularly on protracted crises. Further justification of the methodological approach (in particular the choice of a realist-informed approach to data extraction and analysis) is given in Chapter 4.

7.2 Research paper cover sheet – paper 5



London School of Hygiene & Tropical Medicine
Keppel Street, London WC1E 7HT

T: +44 (0)20 7299 4646

F: +44 (0)20 7299 4656

www.lshtm.ac.uk

RESEARCH PAPER COVER SHEET

Please note that a cover sheet must be completed for each research paper included within a thesis.

SECTION A – Student Details

Student ID Number	1806401	Title	Dr
First Name(s)	Sharif Adel		
Surname/Family Name	Ismail		
Thesis Title	Resilience to shocks in national vaccination delivery systems: from analysis of shock effects to resilience-strengthening intervention approaches in Lebanon		
Primary Supervisor	Professor Josephine Borghi		

If the Research Paper has previously been published please complete Section B, if not please move to Section C.

SECTION B – Paper already published

Where was the work published?	BMC Health Services Research		
When was the work published?	23/10/2022		
If the work was published prior to registration for your research degree, give a brief rationale for its inclusion	N/A		
Have you retained the copyright for the work?*	Yes	Was the work subject to academic peer review?	Yes

*If yes, please attach evidence of retention. If no, or if the work is being included in its published format, please attach evidence of permission from the copyright holder (publisher or other author) to include this work.

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. (Attach a further sheet if necessary)	I conceived the review; designed the protocol with methodological input from SB and JB; performed the literature searches; selected studies from inclusion with support from STL; extracted the data with support from STL; synthesised the data; wrote the first full draft of the manuscript; revised the manuscript with supervisory input from JB, KB and SB, and incorporating revisions from all authors.
--	---

SECTION E

Student Signature	Sharif Ismail
Date	02/12/2022

Supervisor Signature	Josephine Borghi
Date	02/12/2022

7.3 Paper 5: Strengthening vaccination delivery system resilience in the context of protracted humanitarian crisis: a realist-informed systematic review

Authors: Sharif A. Ismail^{1*}, Sze Tung Lam², Sadie Bell¹, Fouad M. Fouad³, Karl Blanchet⁴, Josephine Borghi¹

Affiliations

¹ Department of Global Health and Development, London School of Hygiene and Tropical Medicine, UK

² National University of Singapore, Saw Swee Hock School of Public Health, Singapore, Singapore

³ Faculty of Health Sciences, American University of Beirut, Lebanon

⁴ Geneva Centre of Humanitarian Studies, Faculty of Medicine, University of Geneva, Switzerland

* Corresponding author:

Sharif Ismail

Department of Global Health and Development

London School of Hygiene and Tropical Medicine

E: sharif.ismail@lshtm.ac.uk

Keywords:

Vaccine, vaccination, humanitarian crisis, protracted crisis, refugee, health system

7.3.1 Abstract

Background

Childhood vaccination is among the most effective public health interventions available for the prevention of communicable disease, but coverage in many humanitarian settings is sub-optimal. This systematic review critically evaluated peer-review and grey literature evidence on the effectiveness of system-level interventions for improving vaccination coverage in protracted crises, focusing on how they work, and for whom, to better inform preparedness and response for future crises.

Methods

Realist-informed systematic review of peer-reviewed and grey literature. Keyword-structured searches were performed in MEDLINE, EMBASE and Global Health, CINAHL, the Cochrane Collaboration and WHOLIS, and grey literature searches performed through the websites of UNICEF, the Global Polio Eradication Initiative (GPEI) and Technical Network for Strengthening Immunization Services. Results were independently double screened for inclusion on title and abstract, and full text. Data were extracted using a pre-developed template, capturing information on the operating contexts in which interventions were implemented, intervention mechanisms, and vaccination-related outcomes. Study quality was assessed using the MMAT tool. Findings were narratively synthesised.

Results

50 studies were included, most describing interventions applied in conflict or near-post conflict settings in sub-Saharan Africa, and complex humanitarian emergencies. Vaccination campaigns were the most commonly addressed adaptive mechanism (n=17). Almost all campaigns operated using multi-modal approaches combining service delivery through multiple pathways (fixed and roving), health worker recruitment and training and community engagement to address both vaccination supply and demand. Creation of collaterals through service integration showed generally positive evidence of impact on routine vaccination uptake by bringing services closer to target populations and leveraging trust that had already been built with communities. Robust community engagement emerged as a key unifying mechanism for outcome improvement across almost all of the intervention classes, in building awareness and trust among crisis-affected populations. Some potentially transformative mechanisms for strengthening resilience in vaccination delivery were identified, but evidence for these remains limited.

Conclusion

A number of interventions to support adaptations to routine immunisation delivery in the face of protracted crisis are identifiable, as are key unifying mechanisms (multi-level community engagement) apparently irrespective of context, but evidence remains piecemeal. Adapting these approaches for local system resilience-building remains a key challenge.

7.3.2 Introduction

Childhood vaccination one of the most effective interventions in the armoury available to public health policymakers and practitioners (42–46), but there are major impediments to effective delivery in humanitarian settings and vaccination coverage in many of these contexts is low (47,48). Vaccine-preventable diseases (VPDs) have historically been, and continue to be, a

major cause of mortality and morbidity population-wide, can undermine health service capacity through health worker absence due to illness, and lead to long-term reductions in economic productivity (46,306–308). In humanitarian settings, risks are intensified both to displaced populations (to whom vaccination delivery is often disrupted and in whom the prevalence of important risk factors for poor outcomes, such as malnutrition, tend to be higher than for settled populations) and to host communities (through disruptions to vaccination programme and indirectly through risks to herd protective effects).

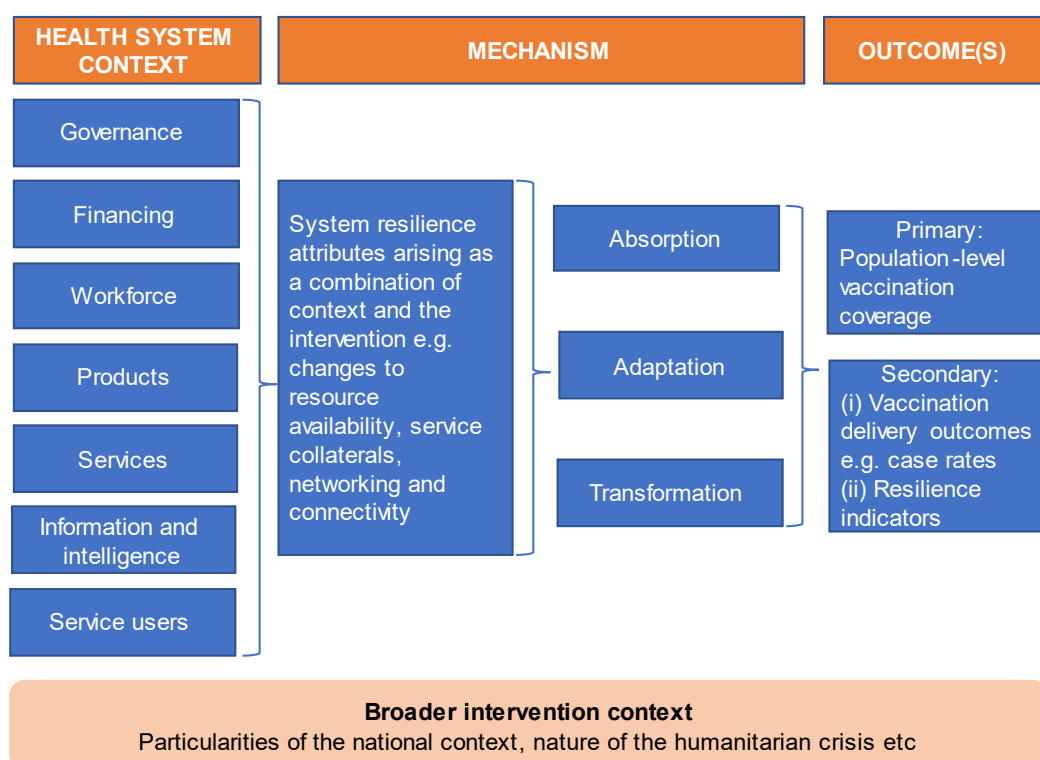
The challenge of low coverage in humanitarian settings is compounded by a long-term shift in displacement patterns in humanitarian crises away from camps towards informal, urban or peri-urban settlements in which over 80% of refugees globally now reside (66–68). Populations living in these areas are often more mobile than those in camps, posing challenges for service delivery and for health information systems, especially so because many vaccines require multiple doses to ensure adequate protection. They also experience more pronounced barriers to care access through both national systems (in countries in which refugees and host communities are served through common public service pathways), and agency-led delivery systems (in countries where refugees continue to be served primarily through parallel arrangements). The evidence base to address this in crisis-affected settings is piecemeal (51,52,309). Most guidance focuses on acute rather than protracted crises (82,84), with little or no consideration of resilience-building or promoting measures that might improve national system resilience over the long-term.

The aim of this review was to identify system-level interventions to strengthen health system capacity to maintain and improve vaccination coverage in protracted humanitarian settings by bolstering the resilience of delivery systems. We use the definition of system resilience employed by Blanchet *et al* in their work on resilience governance, namely “the capacity of a health system to absorb, adapt or transform when exposed to a shock...and still retain the same control over its structure and functions” (10). This approach sets out three main mechanisms for system resilience: absorption, involving delivery of services at the same level (in terms of quantity, quality and equity) and using the same resources and capacities; adaptation, in which services are delivered at the same level but with fewer and/or different resources; and transformation, in which health system actors transform the structure and function of the system to respond to environmental change (10). The term “humanitarian crisis” also encapsulates a very wide range of contexts in which the pressures experienced by health systems, and the spectrum of appropriate responses to these, is considerable. Our analytical approach therefore drew on an emerging body of realist review work focusing not just on identifying which interventions work, but more particularly explaining *how* they work, and contextual factors shaping this (259,260), with a view to tailoring findings to different settings.

We developed a guiding conceptual framework that linked important health system functions (encapsulated by the health system building blocks) and aspects of the wider operating context, to mechanisms, and finally vaccination delivery-related outcomes, as illustrated in Figure 31. Given the diversity of intervention types considered here, developing a unitary programme theory (in line with convention for realist reviews) was neither feasible nor desirable. Instead, our focus was on describing the putative mechanisms by which included interventions worked, as an adjunct to a systematic review methodology (261–263). The process by which the conceptual framework was derived is outlined in more detail in **Appendix 9**.

Figure 31. Guiding conceptual framework for the review.

The framework links contextual aspects (conceptualised using the WHO building blocks framework, but also conditions linked to the broader national context and aspects of the specific humanitarian crisis in the setting for each intervention) and activities strengthening resilience attributes, the mechanisms for enhancing system resilience (absorption, adaptation, transformation) and finally the vaccination-related outcomes achieved (in this case population-level vaccination coverage for antigens included in the review). For more detail on how this framework was developed, please refer to **Appendix 9**.



7.3.3 Methods

This was a realist-informed systematic review of peer-reviewed and grey literature. The review was performed in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (PROSPERO protocol reference CRD42021273124 – available [here](#) and in **Appendix 10**). We considered evidence relating to vaccination delivery for refugee, internally displaced and host community populations in LMICs affected by protracted humanitarian crises with a particular focus on children aged 0-5 as the target population for most routine vaccination programmes, but incorporating older displaced children, teenagers and adults in consideration of, for example, catch-up programmes.

7.3.3.1 Definitions, inclusion and exclusion criteria

There is no broadly agreed definition of the term “protracted crisis” in the literature. We adopted the approach used in the Global Humanitarian Assistance Reports, including any country subject to at least five, consecutive years of UN-coordinated humanitarian action at any point between 2001 and 2021 (310). A shortlist of eligible countries was generated using this approach to determine which contexts to include in searches (see **Appendix 11**).

We gathered evidence on system strengthening interventions aimed at one or more of the WHO health system building blocks at meso- or macro-level, with explicit or potential effects on either or both of the primary and secondary outcome domains set out below. For inclusion, [i] there needed to be sufficient programmatic detail in the article to form a clear view of intervention design and how it had been implemented, and [ii] interventions had to operate at meso- or macro-level. Meso-level interventions included supply-side measures such as area-based interventions (i.e. district, governorate or equivalent level and above), health sector interventions addressing system resilience directly, or alternatively specifying activities under one or more of the WHO’s six health system building blocks; or interventions targeting specific tranches of the vaccination delivery pathway e.g. cold-chain maintenance; or demand-side interventions focused on refugee or otherwise displaced populations in crises with demonstrated effects on population health outcomes (e.g. cash transfer programmes), with the overall objective of increasing population demand for, and uptake of, vaccination. Macro-level interventions, on the other hand, addressed system resilience at national level directly, or concurrently addressed a number of the WHO’s six health system building blocks at national level; or described interventions targeting specific tranches of the vaccination delivery pathway at national level. Micro-level interventions such as the use of tailored text-messaging or other forms of individualised outreach were excluded from the review. Shorter-term activities such as vaccination campaigns were included provided there was demonstrable evidence that these contributed in some way to longer-term resilience-promotion (e.g., through training of

workforce cadres, leveraging of existing structures in new ways). A full outline of inclusion and exclusion criteria is given in Table 12.

Table 12. Inclusion criteria applied in the selection of studies for this paper.

Domain	Criteria
Study type	<ul style="list-style-type: none"> Journal articles, conference abstracts, agency and NGO evaluation reports, government reports and plans, presentations, WHO SAGE documents, guidelines and guidance documents For peer-reviewed papers, study designs may span systematic reviews and meta-analyses, randomised controlled trials, interrupted time series analyses, repeated cross-sectional studies, qualitative analyses (i.e., primary studies). Grey literature sources will need to report original findings from population-based studies of the kinds identified above, or programme or policy evaluations. Formats may include formal reports, working papers, PowerPoint presentations etc. Sources that neither cite nor directly report research results will be excluded.
Search period	01/01/2001-09/11/2021
Populations	Refugees, internally displaced populations and host communities in settings meeting the geographical inclusion criteria set out below.
Intervention type	For inclusion, the paper must have an interventional focus, must describe a macro or meso-level intervention as outlined in the main body of the paper, and crucially, must provide detail on the mechanism by which the intervention acted. Micro-level interventions were not included. Finally, studies had to report against one or both of the outcomes (primary or secondary) identified below.
Immunisation focus	Articles referencing any or all of the antigens listed in WHO guidance on interventions for application in humanitarian emergencies(82) – specifically: Cholera, Diphtheria, Haemophilus influenzae type b, Hepatitis A, Hepatitis B, Hepatitis E, Human papillomavirus (HPV), Influenza, Japanese encephalitis, Measles, Meningococcal disease, Mumps, Pertussis, Pneumococcal disease, Poliomyelitis, Rabies, Rotavirus, Rubella, Tetanus, Tuberculosis, Typhoid fever, Varicella, Yellow fever
Geographical coverage	LMICs (defined according to World Bank Country and Lending Groups classification) with significant refugee or internally displaced populations and included according to whether they met a pre-determined “protracted crisis” definition, based on duration of humanitarian or refugee response plan coverage during the study period (see Appendix 11).
Outcomes	The primary outcome measure was population level vaccination coverage for any of the antigens listed above. Secondary outcome measures included vaccination delivery metrics such as drop-out rates, reported caseload for vaccine-preventable diseases; and resilience metrics (variable according to the study).
Languages	Arabic, English and French

7.3.3.2 Outcome measures

The primary outcomes of interest in this study were population level vaccination coverage for the vaccines outlined in the aims and objectives section above (defined according to the WHO schedule). We also considered secondary outcomes in two categories: [i] vaccination delivery outcomes as defined by included studies but including rates and reported caseloads for vaccine-preventable diseases (VPDs); access to routine immunization (typically defined as the proportion of eligible children within a given time period in receipt of a particular antigen dose); drop-out rates (for multiple dose regimens); and [ii] system resilience indicators where these were given e.g. the presence of systems for protecting financing for vaccination, composite measures such as facility readiness metrics, available vaccine stock, workforce numbers and reserve and so on (with variations from study to study according to design and setting).

7.3.3.3 Identification of studies

Keyword-structured searches were performed in MEDLINE, EMBASE and Global Health (all via Ovid), CINAHL (via EBSCOHost), the Cochrane Collaboration and WHOLIS. These were accompanied by targeted searches for grey literature through the UNICEF, Global Polio Eradication Initiative (GPEI) and Technical Network for Strengthening Immunization Services (Technet – <https://www.technet-21.org/en/>) websites, because of the role these organisations and initiatives have played in producing and collating evidence and technical guidance to support routine immunisation delivery including in humanitarian contexts. All literature searches were performed between 3rd and 9th September 2021. A sample search strategy is provided in **Appendix 12**.

7.3.3.4 Selection of studies

Studies were independently screened for inclusion on title and abstract, and then full texts reviewed by two members of the research team working independently, using the criteria outlined in Table 12. The first stage of screening (title and abstract) for articles identified through established search engines was performed using Rayyan QCRI, a free web application to support the conduct of systematic reviews by researchers working remotely (311). For results obtained from the UNICEF, GPEI and TechNet websites, initial screening was performed in MS Excel because it was not possible to download full reference details in an appropriate format for use in referencing software. Full text screening for all sources was conducted exclusively using MS Excel, and with reference to article PDFs. At each step, disagreements were resolved based on discussion between the two members of the screening pair.

7.3.3.5 Data extraction, assessment of study quality, and data synthesis

Data were extracted in duplicate from each included study using a pre-developed extraction template in MS Excel (**Appendix 13**). The extraction template was structured around the context-mechanism-outcome triumvirate emphasised in guidance on realist reviews (260,312). The template gathered basic study characteristics, general features of the intervention context (including the type of humanitarian crisis, and whether the intervention was geared towards prevention or outbreak response), the target disease; data on intervention structure using an approach informed by the WHO's health system building blocks but including additional components such as service-user-focused aspects (demand management approaches such as community mobilisation and communications initiatives to bolster vaccination uptake); and finally measured outcomes. Importantly, the tool focused specifically on how inputs contributed to absorption, adaptation or even delivery system transformation (i.e., the intervention mechanism). Findings were synthesised using a thematic approach informed by the framework given in Figure 31.

Study quality was assessed independently using the Mixed Methods Appraisal Tool (MMAT), a validated tool developed which has been developed to help facilitate appraisal of public health research studies with multiple study designs and interventions within a single framework (313). Results from the duplicate extractions were inspected and areas of disagreement resolved by discussion between the two authors engaged in the extraction.

7.3.4 Results

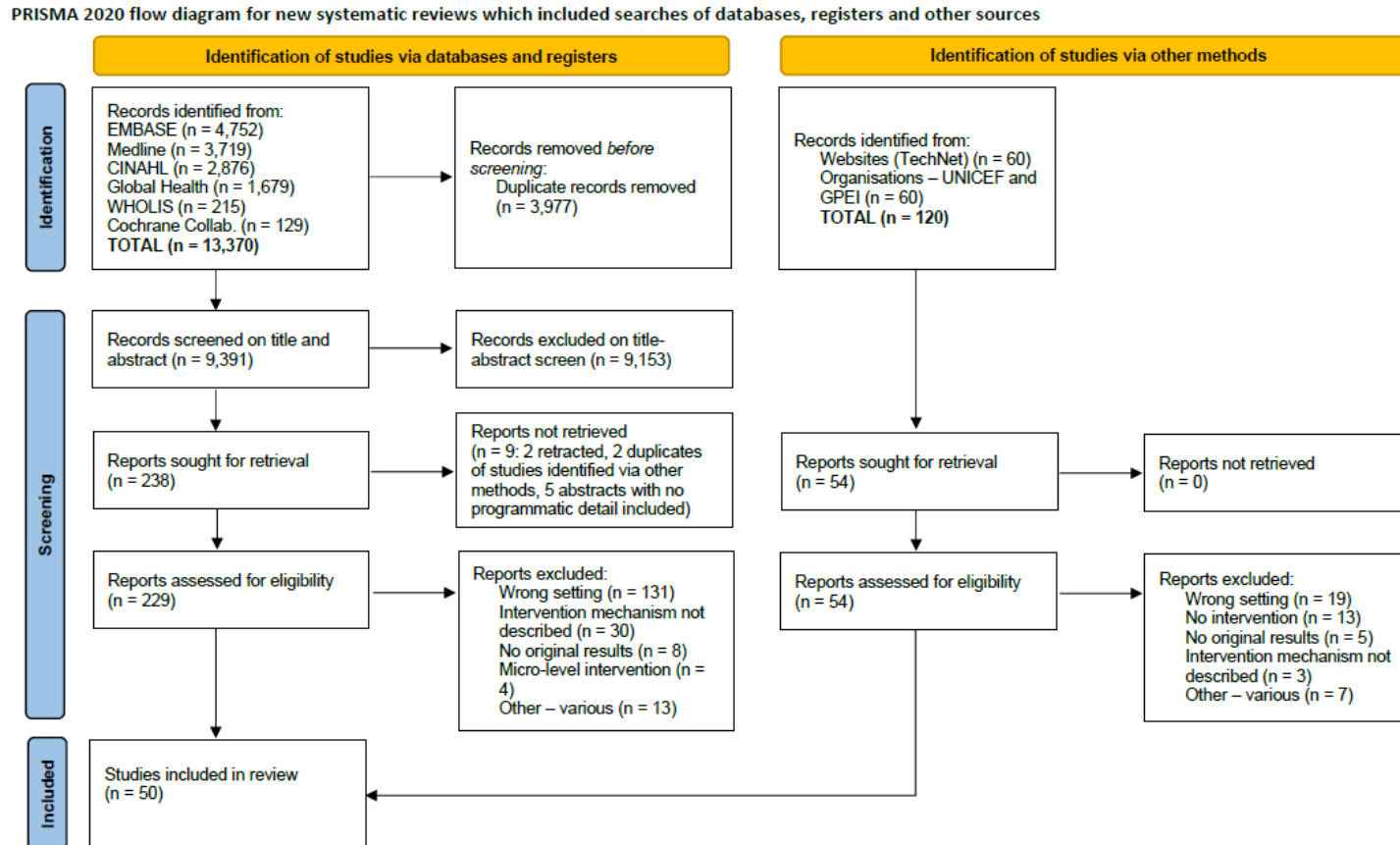
A total of n=50 studies focused on childhood vaccination delivery were included after screening (see the flowchart in Figure 32, quality appraisal summary in **Appendix 14**, and summary table in **Appendix 15** for further details). Included studies addressed interventions implemented in a range of settings, but the largest number of studies were from Nigeria (n=15, 30%), followed by South Sudan and Afghanistan (n=4, 8%), and Cameroon, Haiti and Somalia (n=3, 6%). Four studies (8%) addressed interventions applied across multiple settings. There was considerable diversity in health system and wider crisis contexts in which interventions were being implemented. Considering crisis settings, over half of the included studies described interventions in settings of active conflict or that were immediately post-conflict (n=27, 54%); a third were implemented in complex humanitarian emergencies including large-scale population displacement (n=18, 36%); and two studies (4%) focused on interventions implemented in the aftermath of natural disasters (Figure 33). Further detail on contextual settings is provided below.

We identified eight broad intervention classes (Figure 33), of which the commonly described were vaccination campaigns (n=17, 34%). Eight studies (16%) addressed multi-dimensional interventions, some of which included campaigns as one aspect of what was delivered but might also incorporate community mobilisation activities and governance or surveillance system strengthening among other activities. Health financing interventions were addressed in 7 studies (14%), including an evaluation of the effects of aid on immunization-related outcomes, and 2 studies on the application of national performance incentive policies implemented at the level of facilities or health workers. Community engagement activities were also considered in 4 studies (8%). Other papers addressed more narrowly focused interventions such as service integration (n=6, 12%), those geared towards improving governance coordination in vaccination delivery (n=3, 6%), health information (n=3, 6%) and health workforce (n=2, 4%). Finally, most studies addressed either interventions targeting multiple antigens from the routine schedule (n=17, 34%) or those aimed at improving coverage of different classes of poliomyelitis immunisation (n=19, 39%). A smaller number considered cholera or measles vaccination specifically.

A large majority of included studies (n=29, 58%) were mixed-methods program evaluations, but methodological approaches across the complete set were diverse. We did not identify any systematic reviews that explicitly addressed vaccination delivery in humanitarian settings and met the inclusion criteria for the study – specifically with regard to intervention design and delivery. This partly reflects a primary focus of this study on gathering information on intervention mechanisms, as well as measured effects.

Figure 32. PRISMA flowchart describing the results of the screening and article selection process.

In this review, the selection process is described in two flows; one relating to peer-reviewed literature sourced through formal databases (the left-hand stream), and one describing selection of peer-reviewed, grey and other sources identified through searches of organisational and other websites relevant to vaccination delivery (right-hand stream).

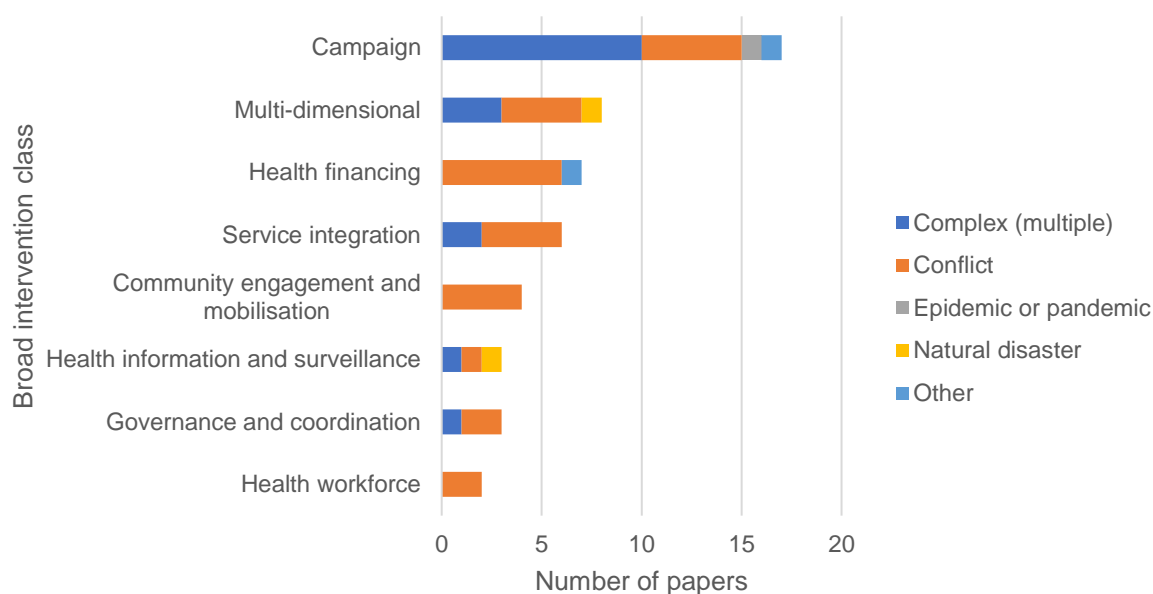


*Consider, if feasible to do so, reporting the number of records identified from each database or register searched (rather than the total number across all databases/registers).

**If automation tools were used, indicate how many records were excluded by a human and how many were excluded by automation tools.

From: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ* 2021;372:n71. doi: 10.1136/bmj.n71. For more information, visit: <http://www.prisma-statement.org/>

Figure 33. Breakdown of included articles by intervention class and the type of humanitarian context described. Campaigns were the most-commonly described interventions, and predominantly from complex humanitarian crisis settings.



Significant methodological limitations were identified across almost all of the included studies (see summary MMAT judgements in [Appendix 14](#)). Table 13 provides a summary of the principal intervention types identified in the review, the mechanisms by which these were seen to act (in all cases either adaptive, transformative or potentially transformative), a summary of relevant outcomes, and some of the key contextual modifiers in each case. A study-by-study summary of results is given in [Appendix 15](#). As Table 13 shows, most included interventions supported system resilience through adaptation. Although reported outcomes varied according to the study, some important contextual modifiers were identified that cut across a number of studies, including: the level of insecurity in the operating environment; the level of population trust in providers; and the existence of pre-existing health system infrastructure (especially linked to polio eradication activities in security-compromised areas) around which to implement new interventions. The remainder of the results section is organised according to broad intervention class, beginning with vaccination campaigns. In each section, details of intervention mechanism are given alongside relevant contextual information to help explain how and why the intervention took the form that it did.

<i>Intervention class</i>	<i>Intervention type</i>	<i>Mechanism</i>	<i>Outcomes</i>	<i>Contextual modifiers</i>	<i>Relevant studies</i>
Campaign		Adaptive.	Variable according to campaign structure approaches (see Appendix 15). All studies noted increases in coverage post-campaign but with variations according to geography or population group.	Wide variety of contexts described. Active conflict/insecurity strongly influenced choice of service delivery modality, in particular the extent to which community mobilisers were involved in demand-generation activities.	(314–330)
Health financing	Payment for performance	Adaptive	Variable evidence of effects on coverage for selected antigens depending on the study – one showing a positive effect, one showing no effect, and one showing a marginal decrease in coverage over time.	All included studies applied in conflict-affected settings. (Positive) wider health system financing environment likely to have influenced outcomes in one of these studies (331).	(331–333)
	Funding disbursement	Adaptive	Rapid decline over time in difference between funds disbursed to health workers and funds accounted for.	Applied in conflict-affected setting only. Availability of a partner bank in-country with capacity to support mobile phone-based funding disbursement important to intervention delivery.	(334)
	Private sector engagement	Transformative	Statistically significant increase in coverage for selected antigens in intervention area by comparison with controls.	Community-embeddedness of the intervention – through engagement of local councils – was important in supporting demand for vaccination through the public-private partnership.	(335)
	Development financing	Adaptive	Improvements in coverage for selected antigens over time following uplift in macro-level financing.	Relevant countries included in both studies were primarily conflict-affected, with significant and ongoing disruption to health service delivery.	(336,337)

Service integration	Mobile Health Teams	Adaptive	Improvements in coverage for selected antigens over time but with variations across population groups.	Both interventions applied in conflict-affected settings. Existence of established governance mechanisms (linked to agreed basic package of care in one study, and a strategic plan and accountability framework in the other)	(338,339)
	Nutrition and routine immunisation	Adaptive	Increases in number of children immunised in one study (coverage not reported) and coverage for selected antigens in the second study following implementation.	Both studies implemented in South Sudan in context of ongoing instability. Existing service integration policy identified as important success factor for the intervention in supporting pooling of funds across service domains.	(340,341)
	Polio eradication and routine immunisation	Potentially transformative	Increases in coverage for selected antigens following implementation of the integrated interventions.	Both interventions implemented in conflict-affected contexts. Ability to mobilise sufficient financial resources to support delivery identified as a key success factor, as well as existence of established polio eradication architecture on which to capitalise.	(342,343)
Governance and coordination	Civil-military engagement	Potentially transformative	Improvements in accessibility for targeted areas noted following intervention implementation, as well as reductions in number of zero-dose children.	Both interventions applied in conflict-affected settings. Existence of governance mechanisms linked military leadership at regional level and the polio eradication programme in each country identified as an important factor in promoting civil-military engagement.	(344,345)
	Cross-border coordination	Transformative	Improvements in vaccination coverage, case ascertainment for AFP among high-risk populations identified following intervention implementation.	Political commitment from country governments and brokering by WHO identified as important to success of intervention. Contextual challenges tempering effects included ongoing population movement from South Sudan and local factors including a health worker strike in Kenya.	(346)

Health workforce	Volunteer community mobilisers	Adaptive	Reduction in the number of missed opportunities for polio vaccination following intervention introduction.	Supportive infrastructure of the polio eradication initiative in-country identified as key to success of the VCM intervention, as was population-level trust in these providers.	(347)
	Technical surge capacity	Adaptive	Reduction in both missed opportunities for polio vaccination and documented polio cases following intervention implementation.	Substantial funding (in this case from BMGF) identified as an important contextual factor supporting the intervention, as well as prior implementation of a performance and accountability framework in WHO country offices that supported assessment of performance against surge personnel contracts.	(348)
Health information and surveillance	Monitoring and planning	Adaptive	Variable according to the intervention – see Appendix 14 . Reduction in the number of geographical locations with zero vaccination coverage by comparison with control areas in one (GIS-based) intervention. Effectiveness of rapid monitoring for campaign delivery unclear.	Prior experience of the polio eradication initiative with deployment of GIS-based population mapping supported intervention implementation. Continuing population movement undermined the effectiveness of rapid monitoring for campaign targeting in the second study.	(349,350)
	Outreach surveillance	Adaptive	Reduction in reported polio case load, and improvements in performance against a series of AFP surveillance criteria.	Applied in a single post-conflict setting only.	(351)
Community engagement	Community mobilisation activities	Adaptive	Increases documented in vaccination coverage, or reductions in missed opportunities for vaccination depending on the study.	All four studies were implemented in northern Nigeria. An important factor influencing programme success in at least two of the studies included the long-established position of the polio eradication initiative and the supporting infrastructure it provided around which to build community mobilisation activities. Population trust	(352–355)

				in providers was also a key factor influencing success.	
--	--	--	--	---	--

Table 13. Summary of interventions included in the review, the mechanisms by which these supported system resilience, outcomes and key contextual modifiers.

Multi-dimensional interventions are not included in this table because they comprise multiple discrete interventions acting in a variety of ways – please refer to the main text for further information on these.

7.3.4.1 Supply-side interventions

Vaccination campaigns

A total of 17 studies in this category met the inclusion criteria, most (n=10) describing campaigns delivered in complex emergency settings, and a large proportion (n=7) focused on cholera prevention or control, with measles (n=4) and polio (n=3) also commonly targeted pathogens. Most studies were either post-hoc campaign evaluations (n=9) or cross-sectional surveys assessing campaign impact (n=8). These studies were distinguished from material on supplementary immunisation activities (SIAs) by the duration of engagement during the intervention, with an understanding that campaigns were short – up to a maximum of a few months in length for each individual round. Included articles described campaigns delivered in a broad range of country contexts, with the best-represented country again being Nigeria (n=4), and two studies from Cameroon.

All vaccination campaign studies described short-term and adaptive responses to crisis, including mobilisation of significant additional resources (financial, human and other) domestically and from international donors and other non-governmental actors. Those studies reporting the largest effects all concerned multi-component campaigns involving vaccination delivery through multiple service delivery modes (fixed site, mobile clinics and sometimes mass vaccination sites), but accompanied by community mobilisation activities, health worker recruitment and training, and support to cold chain improvement, among other interventions. For example, two linked studies addressing different aspects of the same cholera vaccination campaign among displaced persons in Borno, in northern Nigeria, showed 90% (95% CI 88-92%) first dose, and 73% complete (68-77%) OCV coverage in the target population following a multi-dimensional intervention involving door-to-door and fixed-site delivery modes, multiple information dissemination and communication routes (word-of-mouth, flyers, announcements and media spots) and health worker capacity building. However, the two studies also note important contextual factors contributing to success: the campaign benefited from a long-standing partnership governance model in which the Ministry of Health led but agencies and NGOs supported on the ground delivery, and preparedness in two key areas before the outbreak: training in cholera preparedness that had incidentally been run by the Nigeria CDC earlier the same year, and the licensing of OCV for use in Nigeria in the months prior to the outbreak (323,324).

These studies also emphasised the importance of prior networks built through polio eradication work in Northern Nigeria, and the ability of campaigns to capitalise upon this. Two further evaluation studies from Nigeria, considering polio and measles campaigns respectively, documented the use of polio eradication infrastructure to support short-term activities, including the use of existing GPEI governance structures, outreach capabilities

especially in less secure areas that had been developed previously in partnership with the Nigerian military, and the integration of measles surveillance within case-based information gathering on acute flaccid paralysis (AFP). In these cases, near-term, adaptive responses built on long-term capacities in the vaccination delivery system in Nigeria intended to bolster resilience against the spread of poliomyelitis, although the results reported by the first study should be treated with caution because administrative coverage estimates exceed 100% (316,328).

Two studies from Cameroon considered campaign rollout for cholera and meningococcal vaccines against the backdrop of COVID-19 spread nationally. These studies emphasised the importance of central coordination through the Ministry of Health, the recruitment and training of cadres of vaccination workers (including community mobilisers to enhance outreach into remote and insecure communities) and the use of multiple communication modes with target populations – including through community leaders – to enhance uptake. Both studies reported large improvements in administrative vaccination coverage following the respective campaigns but noted large regional variations. Neither study included a formal cross-sectional survey or time-series analysis to statistically evaluate campaign impact, so results should be treated with caution (314,315).

Drawing transferable lessons from other campaign-focused studies in this review is limited by the diversity in contexts in which they were implemented, ranging from multi-vaccine delivery in low-income settings in the midst of active conflict (319,325), to OCV and MMR deployment among displaced Rohingya refugees in Bangladesh (320). However, common strategies emerge across a number of these studies, including the use of multiple service delivery pathways (318,321,322,327,329), intensive community engagement and mobilisation activities (318,319,322,326,330), and central coordination led by the domestic Ministry of Health (317–321), which in combination were intended to increase vaccination coverage by mechanisms including bringing services closer to users, enhancing awareness of the need for vaccination and trust in service providers.

Health financing

Seven studies considered health financing interventions that ranged in focus from adaptive capacity building to potentially transformative activities. These included two that looked at macro-level financing – specifically the value or otherwise of development aid in promoting improved health outcomes, including for vaccination, and system-strengthening in Gavi-supported countries (336,337); one study that considered private sector provider engagement in routine immunisation provision (335); and four that considered in one way or another

improvements to local level incentives for vaccination delivery (331–334). Of these four, three studies considered explicit incentivisation to facilities or health workers via pay for performance (P4P) (331–333); and one considered improvements to disbursement of programme funds to local level to promote vaccination delivery as a means of reducing the risk of delayed payment to HCWs (334). Most of these studies were from low-income settings in Sub-Saharan Africa, and 5 of the 6 considered interventions in conflict or post-conflict environments. The overall picture from these studies was mixed, as outlined below.

Pay for performance (P4P) and financial disbursement mechanisms

Studies on P4P and disbursement mechanisms involved changes of a potentially transformative nature for system resilience by changing structures and accountability systems governing financing for vaccination delivery. Of the three studies that looked at P4P, two were from time-series analyses from Burundi (331,333) in the near-post conflict period, and one from Afghanistan (332) was a high-quality cluster RCT in the context of an ongoing, complex humanitarian crisis. All involved programmes overseen by the Ministry of Health in each country, but with contracting arrangements to facility level involving humanitarian actors and NGOs in service delivery. One study from Burundi found evidence of an improvement in completion rates for routine vaccination courses, especially for children from poorer households, after the introduction of the intervention (331), but the other two studies found no meaningful effect on vaccination uptake overall. The difference in measured effect may be partly down to intervention design: in Afghanistan incentives were provided directly to healthcare workers, whereas in Burundi payment was issued to facilities. Results in the Burundi study showing a positive effect on completion were also potentially influenced by context, because the intervention was implemented at the same time as a large overall increase in facility level budgets (for which the authors were unable to control) (331).

The study on disbursement mechanisms did not consider any of our primary outcomes but did address intermediate effects (secondary review outcomes) including successful completion of health worker payments, widely understood to be a key operational challenge for programme delivery in LMICs in general, and humanitarian settings in particular (334). In this intervention, the WHO oversaw direct disbursement to the local level through a variety of activities including a newly introduced e-payment system, the establishment of close-to-facility payment sites and later the use of mobile payment systems, with reconciliation of funding distribution through partner meetings and other forms of information exchange. The intervention mechanism was two-fold: [i] to increase funding availability at the local level to support service delivery, and [ii] improve health worker satisfaction and motivation to deliver vaccination, as a result of prompt payment. In this observational study, the number of HCWs successfully paid increased markedly over the course of the programme, and match-up between funds disbursed and

accounted for trended to 100%. This scheme was eventually extended beyond polio, to other routine immunisation workers, to help contribute to long-term system resilience.

Private sector engagement

One study considered the integration of private providers into routine immunisation delivery through a public-private partnership (PPP) in Uruzgan province in central Afghanistan, which had historically suffered from both profound insecurity and chronic underinvestment in primary health care services (335). This cross-sectional analysis found a statistically significantly greater uptake of polio, DTP and measles vaccinations in intervention locations targeted by the PPP by comparison with control areas where access was primarily through mass vaccination campaigns. Involvement of private providers was promoted through a wide-ranging support package including payments to private practitioners (which did not appear to be performance-linked), provision of vaccine doses and consumables, HCW training and financial other forms of support to improve facilities. Private providers were also wrapped into broader community engagement through local councils, to improve awareness of the new service offer.

Development financing and vaccination delivery

Finally, one ecological study looked at the effectiveness of development financing for health in South Sudan, linking macro-level donor and government investment in health to outcomes at national level through a population survey. This study concluded that despite considerable domestic instability, donor funding to support HSS had resulted in statistically significant improvements in measles (11.2% improvement in coverage, +/- 4.2%, $p < 0.001$), DTP3 (13.1 +/- 3.6, $p < 0.001$) and all-vaccination coverage (11.3, +/- 3.0, $p < 0.001$) over 5 years from 2011-2015, albeit from low levels (337). These global findings covered marked variation at sub-national level, for which the study could offer not mechanism-based explanation as data on information on service delivery models and partnerships at this level were not gathered.

Service integration

Six studies considered system adaptation through service integration – four from sub-Saharan Africa and two from South Asia (Afghanistan and Pakistan). Two studies evaluated the impact of Mobile Health Teams (MHTs) offering integrated PHC including vaccination delivery in Afghanistan and Nigeria (338,339); two looked at integration between nutrition and routine immunisation services in South Sudan (340,341); and the final two studies considered integration of routine immunisation with polio outreach activities in Nigeria and Pakistan (342,343). All bar one were observational studies; the final study was a high-quality cluster RCT from Pakistan (343).

Use of Mobile Health Teams

Two studies on the use of MHTs both showed statistically significant improvements in vaccination coverage, although the nature of these effects varied. A well-conducted, case-control study in Afghanistan found significant improvements only in uptake of first dose measles vaccination (338) by comparison with control areas ($p=0.02$), whereas in Nigeria, a document review-informed programme evaluation found improvements in all-vaccination coverage and course completion rates (from 19-55% over the duration of the intervention) in infants aged 12-23 months (339). The mechanisms by which MHTs worked had much in common across contexts, including an element of population targeting (especially in Nigeria where MHTs were deliberately targeted to settlements in the North of the country that were deemed high-risk for further AFP cases); intensive community engagement and outreach activities (integrated into the intervention through the inclusion of community mobilisers into the MHT in Nigeria, but parallel to it in Afghanistan) to promote awareness of, and trust in, services provided; a system of regular visits over time to build local population trust, rather than one-off interactions; and transparency regarding visit scheduling so that service users knew when teams would be in their locality.

Integrating childhood immunisation and nutrition services

Two low-quality, observational studies considered the effect of integrating nutrition and immunisation services through single access points in South Sudan (340,341). Both showed improvements in uptake for routine immunisation following integration, but statistical analysis was rudimentary. In the first of these studies integration was into nutrition clinics in an IDP camp setting (341), whereas the second involved EPI integration into primary healthcare clinics (PHCs) where this service had not previously been provided (340). The community-focus of these integration efforts was important: in the second study, pentavalent vaccination uptake was 23% greater (rate ratio 1.23, 95% CI 1.12-1.36) in PHCs by comparison with paediatric outpatient departments (the control sites), suggesting a service-user preference for close-to-residence delivery settings.

Integrating polio eradication and childhood immunisation services

Two studies addressed integration of routine immunisation and polio services. One of these, a high quality, cluster randomised trial of an integrating routine and polio immunisation activities, compared a control arm offering standard services, with two intervention arms offering an integrated programme of activities including community mobilisation and the use of additional fixed service delivery sites was used in security-compromised areas of Pakistan (the difference between intervention arms was chiefly in the polio vaccine formulation used – OPV in one arm, and IPV in the second). This study showed statistically significant improvements in the proportion of fully vaccinated children (7.3% [95% CI 4.5–10.0] increase

in one arm vs control; and a 9.5% [6.9–12.0] increase in the second arm vs control). In both the intervention arms, the key mechanism changes were [i] the provision of multiple service delivery pathways (collaterals) and [ii] the use of intensive community mobilisation activities that were delivered in a culturally sensitive way (343). The second study, a programme evaluation from Nigeria considering the integration of routine immunisation with polio eradication work, also emphasised culturally appropriate community outreach, through female community volunteer mobilisers, and saw a rise in the proportion of fully immunized children in the catchment areas from around 18% to 49% over the term of the intervention (342).

Governance and coordination

Three studies considered governance and coordination activities, two emphasising adaptive capacity through civil-military engagement, and the final study describing transformative capacity change through inter-governmental cooperation.

Civil-military engagement for improved vaccination coverage in the context of insecurity

The two studies on civil-military engagement both addressed the use of military and/or security personnel to improve access and polio vaccination uptake in security compromised areas of Angola (344) and Nigeria (345) respectively, against a backdrop in both countries of enduring wild- and vaccine-derived polio circulation (including localised outbreaks). Both studies reported increases in uptake and reductions in the number of missed opportunities for vaccination (MOVs) in these settings although methodological limitations especially in the first of these studies limit the extent to which these gains can be ascribed to the interventions themselves. The mode of action of these interventions also differed: in Angola, military personnel were directly recruited to the programme, whereas in Nigeria, a cadre of civilians who had been supporting the military through community engagement in areas affected by the Boko Haram insurgency in the North were used to reach out to potentially eligible individuals. The key hallmark of both these interventions was a “feet on the ground” approach to improving uptake including in areas of significant insecurity, and the use of “hit-and-run” approaches to vaccine delivery with security cover during periods of unrest.

Cross-border governance coordination for VPD prevention and control

A final study considered a cross-border governance and coordination initiative between the Kenyan, Somalian, Ethiopian and South Sudan governments to reduce the risk of polio transmission in the context of ongoing population movement. This was essentially a preparedness and planning intervention in which, with the support of WHO, representatives from respective country Ministries of Health met on a regular basis to identify important formal and informal population crossing points and transit hubs, agree on selection and recruitment

of immunisation staff, and develop materials for workforce training and surveillance strengthening, among other activities. Identified improvements in vaccination coverage, strengthened cross-border situational awareness were reported (346). This could be described as a transformational change in resilience capacity at regional level by introducing and formalising new spaces for cross-border coordination and knowledge exchange that had not previously existed (i.e., wholly new system structures), underpinned by improvements in situational awareness, and connectivity between partner ministries, as well as stronger cross-border planning for future potential outbreaks.

Workforce development, flexibility and surge capacity

Two studies focused on the contributions of workforce interventions to improving vaccination outcomes, operating at different levels: one on the value-added of technical surge capacity to support immunisation delivery at local level, and the second on the contribution of community volunteers in mobilising service users to take up vaccination (although these were addressed indirectly by a number of other studies, covered elsewhere in the results section). Both studies were from Nigeria, and both focused on polio vaccination delivery (347,348). The first study considered ability to bolster surge capacity using variable terms and other contractual changes for national or zonal staff, to enhance technical support to local areas during vaccination deployment. The use of surge technical capacity in this way was linked to progressive improvements in coverage, substantial declines in MOVs (a decrease in the number of localities with >10% of children missed by campaigns from 21% in 2012 to 3% in 2015) and improvements in intermediate indicators (e.g. the frequency with which micro-plans were updated) (348).

The second study looked at volunteer community mobilisers (VCMs) in Nigeria to address persistently low uptake in security compromised areas, vaccine scepticism, and distrust in government and officials. In this study, VCMs had an integrative role including supporting routine immunisation, but also WASH and other intervention promotion. These were financed through stipends and other (material) incentives, but the main livelihood source is elsewhere. This intervention showed evidence of improvements in coverage but also a sharp decline in MOVs (from 4.5% in 2014 to 0.8% in 2018) which the study attributes to high levels of trust in VCMs because of their social position, cultural sensitivity of their approach, engagement modes including house-to-house visits, and their ability to update programme coordinators with critical soft information on pockets of low uptake (347).

Health information and surveillance

Three studies focused solely or primarily on situational awareness through health intelligence and surveillance activities – although as noted elsewhere in the results section, many of the interventions in other categories involved surveillance/health intelligence-focused components. All three studies were concerned with mechanisms for strengthening situational awareness in contexts featuring population movement and/or ongoing insecurity that could undermine the efficacy of more conventional approaches.

Two of the studies considered systems for strengthening awareness for campaign delivery and evaluation. One examined the use of geographical information system (GIS) technology to support microplanning processes for a measles campaign in Nigeria in 2017-18, focusing particularly on applications in conflict-affected northern states where tracking of mobile populations was much more challenging than in stable areas. Specifically, GIS mapping was used to geo-locate population centres to inform the positioning of fixed sites for the campaign, and resulted in a reduction in the number of wards with zero vaccination coverage by comparison with states where standard population estimation approaches were used. The mechanisms by which this intervention were thought to have worked included [i] more accurate enumeration of target populations especially in the context of ongoing population movement, and [ii] a clearer view of ward boundaries than conventional (hand-drawn) approaches – both of which improved microplanning accuracy (349). The second study looked at the use of rapid monitoring approaches to gauge coverage and help improve campaign targeting in post-earthquake Haiti (350). In this study, a convenience sampling approach was used to assess household uptake at regular interviews; findings were used to better target mop-up vaccination activities. This approach helped strengthen resource management during the campaign but proved only partially effective as a monitoring technique because of continuing population movement. For this reason, the authors contended that it would be better suited to chronic rather than acute crisis situations.

A final, descriptive, study from Iraq considered the use of outreach surveillance activities linked to AFP case ascertainment for polio, to help assess uptake and effectiveness of immunisation in Iraq. This intervention involved use of AFP outreach workers to gather soft intelligence on RI delivery to pinpoint areas where microplanning for delivery needed to improve (alongside quantitative health data through immunisation delivery systems), and to help build awareness of services available among affected populations (351). The authors documented improvements in routine immunisation uptake and reductions in reported AFP case numbers through the outreach system.

7.3.4.2 Demand-side interventions: community engagement and mobilisation

Although – as the summary table in **Appendix 15** makes clear – the vast majority of studies referenced community engagement as a trust-building measure to a greater or lesser degree, four studies explicitly focusing on this aspect met the inclusion criteria for the review, all of which concerned multi-dimensional community mobilisation activities (352,354,355), and one of which combined community mobilisation activities with direct observation of polio vaccination by officials to ensure proper administration of vaccination (353). All four were implemented in Nigeria, and most were concerned with improving polio vaccination uptake. Community mobilisation activities in Nigeria all took place in districts in the north and east of the country, against a backdrop of the Boko Haram insurgency, and all involved a strong element of cooperation with local community and religious leaders to build trust with affected communities. These complex interventions involved multiple outreach strategies including the use of roadshows, in-kind incentives (e.g. provision of soap or detergent, foodstuffs), health camps, and communication via multiple channels (355), agreement of mutually convenient vaccination point locations with community leaders (352) among other activities; a number incorporated recruitment and training of VCMs as part of the intervention (354). These strategies were used to encourage service use through demand-generation activities, reducing access barriers by positioning access points in areas where service users were more likely to take them up, and by enhancing trust in service providers.

Study outcomes focused predominantly on measures of administrative coverage and missed opportunities for vaccination. Three of the studies relied on narrative assessments of impact without formal statistical testing (352,354,355); the final study presented a rudimentary time series analysis (353). Two of the four studies found declines in the proportion of children who had not received any OPV doses during the study period (353,354); another showed concurrent, large increases in pentavalent vaccination coverage from an integrated intervention designed to improve uptake in hard-to-reach communities in Northern Nigeria (352), albeit with marked variations across geographies.

7.3.4.3 Cross-cutting and multi-component interventions

Eight studies addressed sustained, multi-dimensional interventions. These interventions also tended to act at multiple levels, spanning macro-level governance and coordination changes, through to health worker training, and community outreach activities. Three of these studies looked at integrated, strategic interventions in response to poliomyelitis outbreaks, all in conflict-affected settings (241,356,357) and all featuring vaccination campaigns as part of the overall package. All emphasised the importance of strengthened coordination between key

actors. A study from Somalia documented the introduction of a national polio control and coordination room to bring together key partners, improve communication and provide a framework for information/intelligence sharing; national coordination mechanisms were important in Ukraine and Syria (241,357); and regional mechanisms were used in Middle East and North African (MENA) countries for the 2017-18 polio outbreak response (242). Multi-modal social mobilisation activities were also central to achievement of improved outcomes.

Of these three studies, two considered regional activities in response to polio outbreaks in conflict-affected countries in the Middle East and North Africa, both involving multi-phase response plans not just to interrupt initial transmission, but then to focus on high-risk areas for importation. These evaluation reports indicate that through intensive community engagement it is possible to raise vaccine coverage even in areas of profound insecurity and constant population movement, but also that focused surveillance is really important in allocating resources appropriately and that multiple data points were triangulated for this (241). The first of these studies emphasised importance of targeting in identifying AFP hotspots, and the contribution of electronic syndromic surveillance systems in picking up emergent VPD case clusters and improving situational awareness (241). Results from the second study indicate that intermittent supplementary immunisation activities (SIAs) can be supportive of long-term system capacity by refreshing training and other essential functions and bolstering support for community outreach and surveillance initially built during an acute outbreak response, although these effects tail off over time (242). This study noted that gradual degradation of systems since the first SIA in 2013-14 may have contributed to the risk of re-emergence of polio cases in Syria in 2017-18 (242).

A further four studies looked at integrated, preventive responses, three focused on SIAs (358–360) and one on a district-level, NGO-led intervention to increase cholera vaccination uptake in urban slums in Haiti following the 2010 earthquake (361). SIAs achieved their measured effects through a combination of community mobilisation activities, capacity building of local health staff, mobilisation of funds from multiple sources (including international donor support) and supply chain strengthening activities. In Somalia, improvements linked to the SIAs contributed to long-term cold chain strengthening for all routine immunisation delivery (358). The district-level intervention in Haiti comprised multiple components including the introduction of new governance mechanisms (a coordinating committee), a communication plan, and re-allocation of the majority of NGO staff to supporting vaccination delivery for the duration of the intervention. This adaptive response to low coverage in their target communities benefited from an ability to surge staff from other areas – a disruptive approach for the NGO's broader activities which is unlikely to have been sustainable beyond the term of the intervention (361).

7.3.5 Discussion

7.3.5.1 Summary of key findings

This review identifies a series of interventions that may support vaccination system resilience capacities for improved routine childhood vaccination coverage (some of which also addressed catch-up vaccination delivery for older children) in settings of protracted humanitarian crisis. Most of these interventions reinforced adaptive resilience capacities but some (especially governance and workforce interventions) had transformative potential even if study results did not necessarily indicate radical change had been achieved within the term of the study. Although the diversity of settings described in this review precludes easy generalisation regarding important contextual factors, more successful interventions relied on leadership from domestic ministries of health, funding and – importantly – flexibility from agency and donor partners, and an ability to negotiate safe access for vaccinators and outreach workers.

Considering adaptive capacity, vaccination campaigns were the most extensively evidenced interventions and while their effects may appear to be short-lived, many of the examples considered here both built on existing capacities and contributed to development of new ones in a range of areas, including through introduction of novel governance structures and workforce capacities developed during previous activities. The most successful campaigns were multi-dimensional interventions that incorporated a mix of service delivery approaches (fixed-site, mobile team and mass-vaccination sites), intensive community mobilisation efforts, health worker training, and supply chain strengthening work. They were also often multi-phased to help both break chains of transmission (where the primary strategic objective was outbreak control) and prevent future outbreaks. The long-term sustainability of capacity strengthening through campaigns necessarily depends, however, on mobilisation of funding and other resources beyond the intervention lifecycle – some of which can be addressed by sustaining intervention through SIAs. None of the studies exclusively focused on campaigns offered detail on sustainability planning post-intervention.

Other adaptively focused interventions included service delivery changes such as service integration and the use of MHTs. All included studies on service integration demonstrated improvements in vaccination coverage and course completion rates albeit with varying effect sizes and in studies of generally low quality. MHTs seemed to improve vaccination coverage by enabling outreach especially into poorer and more marginalised communities, by improving trust through regular interactions and the supporting activities community mobilisers drawn from the communities they served.

Some common mechanisms emerged across the higher-impact interventions identified in the review. For example, strengthening trust and increasing the range of access points were key themes especially among communities living in security-compromised zones, and many interventions directly addressed this through outreach models including the use of community volunteers, messaging through community (including religious) leaders, but also more controversially through cooperation with security personnel. Political and ethical challenges revolving around the deployment of security personnel in support of routine vaccination are considerable and this route is unlikely to be feasible or desirable in all settings. On the other hand, community volunteers were frequently identified as critical in tackling scepticism towards government and officials, but also contributed to bolstering situational awareness through improved case ascertainment for VPDs (as a linked, situational awareness-improving function).

Finally, a large proportion of the papers related directly or indirectly to lesson learning from polio eradication, and the resilience-building contributions PEI infrastructure could make with respect to routine immunization more generally. Particular areas of learning included the use of multi-modal approaches to vaccination and surveillance in security-compromised areas, the value and use of existing outreach networks into communities, and messaging strategies. Objectives for polio control (specifically eradication) are very different to those for many other VPDs where primary aims are more likely to be interruption chains of transmission in the context of outbreaks or to keep the burden of mortality and morbidity low in the face of endemicity (for diseases such as measles for example). This should not, however, preclude the use of infrastructure developed for polio control to support wider routine immunisation objectives.

Evidence in some areas was notable by its scarcity. For example, material on governance and financing was both limited and showed conflicting evidence on vaccination-related outcomes, although some promising interventions were identified in these domains, including the use of direct disbursement mechanisms for health worker payment, and a model of cross-border cooperation in the Horn of Africa to support preparedness and planning to reduce poliomyelitis risk. In addition, while some studies touched on leadership and oversight capacity development, we identified no studies that explicitly focused on leadership models contributing to resilience capacities for routine immunisation. Similarly, evidence on governance reforms such as decentralisation, which have been implemented in some eligible countries (e.g., Kenya and Tanzania) was not forthcoming, although one study briefly considered the importance of decentralised decision-making as a contextual contributor to the success of a nutrition-immunisation integration intervention (340). Finally, although we did not specifically screen to include studies on cost and cost-effectiveness, data on costs associated with

intervention implementation were conspicuously absent from included studies. This is a notable shortcoming given the fundamental importance of sustainable financing for health system resilience especially in crisis-affected settings.

A number of systematic reviews have been published in recent years addressing the effectiveness of interventions in humanitarian settings, some including data on vaccination delivery (309,362), and there is now a large body of evidence considering the effectiveness of interventions to improve vaccination coverage from community level upwards in low- and middle-income settings more generally (e.g. 16). This review is, however, distinctive in its macro- and meso-level interventional focus, in employing a realist perspective to understand how, where and why interventions may be effective, and its emphasis on gathering data from protracted crisis settings. Many existing studies and guidance documents focus on acute-phase responses without consideration to ways in which these may support, or undermine, long-term capacity within the system to respond to changing circumstances on the ground, or the mechanisms by which they may do so (82,83,364).

Nevertheless, many of the central messages from this review – including the value of recruiting local staff to improve trust and vaccination uptake, flexibility in service delivery modes (including the use of mobile services), and use of electronic systems to strengthen supply chain management and health intelligence – support findings from reviews and guidance elsewhere (37,83,362). Findings also suggest that SIAs, as integrative interventions, can have important and wide-ranging effects not just on vaccination uptake, but also on wider system capacity through e.g., workforce training, introduction of new governance and coordination mechanisms, and support to outreach activities. These effects should be balanced against potential undermining effects on routine immunisation through fixed centres that have been observed in some settings (365), but SIAs are likely to remain an important part of the adaptive armoury to expand coverage in humanitarian settings given their effectiveness at picking up children missed through routine delivery (366). In addition, a number of promising practices are identified, including the use of flexible contracting for healthcare workers and novel financial disbursement mechanisms, for which evidence remains limited but which nevertheless could address delivery problems widely acknowledged in these settings.

7.3.5.2 Limitations of the review

Limitations to the findings reported here relate to both the nature of the underlying evidence base, and the way in which the review was conducted. As the quality appraisal results show (see **Appendix 14**), most included studies were observational works with significant methodological limitations. This particularly affected descriptive, quantitative analyses

included in the review (most of them program evaluations). Outcome reporting was in general poor: measures were incompletely described and frequently related weakly to study objectives or included no clear baseline data against which to measure effects. The quality and detail of intervention description was highly variable, making it difficult to tell which particular intervention components were driving reported results.

Although we were careful to use explicit definitions to guide the review, clarity in the wider literature on some of the key terms is lacking and may have contributed to relevant results being missed. For example, we used a response plan-driven definition of protracted crises that assumes that the introduction of a RP coincided fairly precisely with the duration of the crises of interest. This is often not the case: there may be delays of up to several years before RPs are formulated and agreed – as in the case of the Syria Crisis response, for example. Secondly, an important goal of this review was to capture data from a wider range of sources than the peer-reviewed literature alone, to better capture emergent best practice. Structured searching of grey literature sources remains challenging, and it is likely that some relevant material was missed.

As with all systematic reviews, our findings also cannot account for unpublished or negative results. This may explain the lack of data relating to absorption as a resilience mechanism – that they were not reported simply because they involved services performing in much the same way but more intensively (e.g., through changes to service opening hours, workforce redeployment etc). Because of the diversity of intervention types, study designs and study contexts included, it was neither possible nor desirable to produce summary statistics of intervention effects beyond those reported in the results section.

Finally, we noted imbalances in the geographical representativeness of studies included. On one hand, the balance of included evidence was skewed strongly towards unstable, low-income settings. This is unsurprising given that most countries in protracted crisis today fall into this category, but it reduces the potential transferability to middle income countries hosting large, displaced populations today. Evidence from countries such as Jordan, Iran and Turkey, for example – all of which host large populations displaced by conflict – was notably absent in this review. On the other, a large proportion of included studies were conducted in Nigeria – reflecting historical challenges with vaccine delivery and particularly polio control in the north of the country.

7.3.5.3 Policy implications

Findings from this review suggest that no “silver bullet” solution exists to promoting resilience in vaccination delivery systems in protracted humanitarian crises, and adaptations are likely

to be needed across a range of fronts to address significant access barriers (many of which stem directly from population displacement and chronic insecurity), low trust in service providers, and limitations to effective VPD prevention and control imposed by national borders. Periodic intensification of vaccination delivery via campaigns and SIAs is likely to be a mainstay of adaptive responses to crises whatever the context, to account for shortfalls in routine delivery. However, there is a strong steer from this work for recruitment of non-traditional workforce cadres from within affected communities – including community mobilisers – to help enhance uptake over the long-term, especially in security compromised areas where trust in government and agency representatives may be low.

Resilience in vaccination coverage is also likely to be enhanced through the concurrent use of multiple service channels to reach affected populations, including MHTs and integration with in-demand services such as nutritional support. However, there will inevitably be trade-offs in cost terms to expanded service availability in this way given resource constraints in many humanitarian settings, and the success of any of these interventions will ultimately depend on the willingness of domestic and international actors (including donors) to ensure stability in funding flows to crisis-affected countries.

7.3.5.4 Conclusion

Strengthening the resilience of vaccination delivery systems in protracted humanitarian crises depends on system adaptation across a range of areas, including bolstering access through strengthened outreach, multiple service pathways and better integration with other essential services, as well as demand-generation activities. Future work should consider evidence not just on adaptive and transformative measures to support improvements in vaccination coverage in these settings, but also economic analyses given the significant resource constraints under which decision-makers in humanitarian contexts have to operate.

7.3.6 Declarations

7.3.6.1 Ethics approval and consent to participate

This review was based entirely on data from sources already in the public domain. No ethical approval was required.

7.3.6.2 Consent for publication

Not applicable.

7.3.6.3 Competing interests

The authors declare that they have no competing interests.

7.3.6.4 Funding

SAI is funded by a Wellcome Trust Clinical Research Training Fellowship (no 215654/Z/19/Z).

7.3.6.5 Authors' contributions

SAI, SB, KB and JB conceived the study. SAI, SB and JB contributed to the design of the work. SAI acquired data for the review through systematic literature searches; SAI, LST and SB contributed to the selection of studies for inclusion and acquisition of data. All authors contributed to the interpretation of data. SAI drafted the full draft of the manuscript. All authors revised the manuscript, read and approved the final version.

7.3.6.6 Acknowledgements

The authors thank Kate Perris from the Library and Archives Service at London School of Hygiene and Tropical Medicine for advice on the search strategy for the review.

7.3.6.7 Availability of data and materials

All data generated or analysed during this study are included in this published article and its supplementary information files.

7.4 Situating review findings in the Lebanese context: policy implications

The review highlights a series of potential interventions, a number of which have already been implemented at various points in Lebanon, to help address changing service demand in the face of shocks. Returning to Meadows' system leverage points framework, we can map approximately how and where in the system these interventions might act (Table 14). Outstanding intervention areas identified in this analysis mostly concern those in which evidence from the review was weaker – including financial disbursement mechanisms to facility level, and the use of outreach surveillance and population mapping.

No	Type of lever	Leverage point	Leverage points identified through the analysis	Example interventions by leverage point
12	Events or patterns of behaviour within the system	Constants or parameters within the system	<ul style="list-style-type: none"> Aggregate financial inputs into the system Number of vaccine doses available to administer through PHC network Number of clinic attendances for vaccination Cost of vaccination to service users (at facility level) 	<ul style="list-style-type: none"> Humanitarian response funding Procurement with UNICEF support to maintain supply at facility level at nominal cost to service users Multiple – spanning vaccination campaigns and SIAs, community engagement work, diversification of service access points including MHTs/MMUs, others Policy change to reduce the cost of vaccination to service users through the PHC network
11	System structure(s) explaining events and patterns of behaviours	Buffers	<ul style="list-style-type: none"> Human resource availability at central (policy) and facility (doctors, nurses, managers) level Implementing partner funding to facilities 	<ul style="list-style-type: none"> (Temporary) donor funding of staff salaries; change in currency of payments to staff during the economic crisis Use of surge technical advisers Regular, contracted funding to maintain services, combined with surge funding to manage near-term demand increases (before donor response funding was mobilised)
10		Stock-and-flow structures	<ul style="list-style-type: none"> Physical infrastructure supporting the cold chain to facility level 	<ul style="list-style-type: none"> Introduction of solar fridges; cycling back of vaccine vials to district level when local electricity supplies unreliable
9		The length of important time delays	<ul style="list-style-type: none"> Time to identification that a shock was unfolding Time to mobilisation of donor funding Time to distribution of vaccine doses from the national storage warehouse to facility level 	<ul style="list-style-type: none"> N/A Fast financial disbursement mechanisms Implementation of an electronic stock management system at the central warehouse in Karantina
8		The strength of balancing feedback loops	<ul style="list-style-type: none"> Loop linking PHC crowding to staff willingness to vaccinate and vaccination uptake during COVID-19 	<ul style="list-style-type: none"> Staff training in infection prevention and control; provision of PPE; patient flow measures including clinic cancellations or use of pre-arranged appointments
7		The strength of reinforcing loops	<ul style="list-style-type: none"> Loop linking nurse-led administration vaccine administration to vaccination uptake 	<ul style="list-style-type: none"> Financial incentives to PHC managers to promote nurse-led vaccination

				<ul style="list-style-type: none"> Community engagement work to increase service user trust in nurse-led vaccination
6	Information and controls systems influencing how the system works	The structure of information flows	<ul style="list-style-type: none"> Perception of changing demand for vaccination services at facility level (tracking of vaccination uptake) 	<ul style="list-style-type: none"> Introduction of new e-record systems to document uptake and facilitate identified of MOVs Use of outreach surveillance and GIS-based population mapping to target interventions
5		System rules	<ul style="list-style-type: none"> Norm-setting capability (legitimacy) of MoPH 	<ul style="list-style-type: none"> Financial and technical support from donors and agencies to procure vaccines for the EPI program Contracts between the MoPH and private providers to provide vaccines at nominal cost and report uptake in exchange for free doses
4		Self-organisation	<ul style="list-style-type: none"> Parallel service pathways to maximise opportunities for access to vaccination 	<ul style="list-style-type: none"> Selective use of MMUs, opening of border crossing sites Service integration (various models)
3	Mental models (values, beliefs and assumptions) that govern how the system works	System goals	<ul style="list-style-type: none"> Importance attached to vaccination vis-à-vis other strategic priorities for health actors Strategic orientation regarding the inclusion of refugees as a target population for vaccination through the PHC network 	<ul style="list-style-type: none"> LCRP and MoPH strategy documents underscoring the prioritisation of vaccination Policy change to open PHCs as a common access point for Syrian refugees and host communities, for vaccination at nominal charge
2		The paradigm out of which the system arises	N/A	N/A
1		Transcending paradigms	N/A	N/A

Table 14. Mapping system leverage points identified through the thesis against purposeful interventions implemented to support vaccination delivery in Lebanon since 2012. For reasons of space this table is indicative rather than comprehensive. Interventions identified by the review but previously implemented in Lebanon are highlighted in green; areas of partial implementation are in orange; and new intervention areas are highlighted in red. Other interventions, implemented in Lebanon but not specifically identified through the review, are given in regular text.

Chapters 5 and 6 highlighted the importance of periodic vaccination campaigns and SIAs in Lebanon both to address urgent needs following peak periods of refugee arrival in 2013-15, to help stem the national measles outbreak in 2018-19, and to address missed opportunities for vaccination (MOVs) more recently. MHTs (referred to as MMUs in the Lebanese context) have also been used at various points for outreach to rural communities and marginalised groups, particularly in the initial phases of the Syria Crisis Response. Having fallen out of favour with MoPH officials for a time because of concerns over quality of care and cost-effectiveness, MMUs have returned in limited form for both deployment of COVID-19 vaccination and for catch-up routine immunisation because of the physical access difficulties service users in Lebanon are increasingly facing. Finally, community health workers have for some time been a key part of the outreach component of demand-generation work across populations, through agreements between UNICEF and implementing partner organisations, for example.

Some of the described interventions have also been partially implemented. For example, public-private partnerships with private clinics have been a key delivery objective for the MoPH for some years, to help establish greater regulatory control over what vaccinations are delivered to children in Lebanon and when, as well as for reporting purposes. In Chapters 5 and 6 we saw how entrenched opposition to this from the private sector collapsed in 2021/22 as economic conditions worsened, demand fell, and private physicians found themselves without vaccine doses they could administer. There is clear scope for increasing the reach of this initiative through recruitment of additional private providers.

A final set of interventions identified in the review have not, to date, been implemented. In some instances, this is plainly on grounds of practicality. For example, engagement or interaction with military and security personnel to bolster uptake has not been attempted and is unlikely to be seen as practical or desirable in Lebanon given historically fragile relations between armed non-state actors and state institutions, especially in South Lebanon and the Bekaa.

On the evidence presented above, however, service integration looks promising as an avenue for strengthening resilience in vaccination delivery in Lebanon. This is already offered to a degree through the PHC network in Lebanon, but only in the context of delivery of mainstream health services. A central finding from the qualitative work in Chapter 5 was that service users were increasingly prioritising subsistence needs over preventive health interventions such as vaccination, as the economic crisis in Lebanon increasingly took hold. There is, therefore, a potential opportunity to further integrate provision of WASH, basic nutrition and other

interventions (e.g., access to sanitary products) with routine immunisation or advocacy around the need for vaccination, especially within the inter-sectoral framework of the LCRP.

Finally, there may be scope to look at rapid financial disbursement models to facility-level staff. Although the evidence presented on this approach in the review is limited, it would address one of the principal delays identified in the CLD and would also help to address one of the main barriers to health worker retention in the current economic climate in Lebanon. However, rapid disbursement models are likely to be implementable only with the support of implementing partner NGOs, without whose financial and material resources many PHCs would have ceased functioning over the past two years.

7.5 Chapter summary

This chapter has identified a series of interventions that can bolster resilience in vaccination delivery systems, drawing on the international literature. It has also related these to activities already ongoing in Lebanon, highlighting some areas where the existing service offer could be further strengthened – e.g., through integration. As the review findings in this chapter make clear, however, there is no “silver bullet” intervention. Long-term resilience-building will depend on a combination of measures, and an ability (and willingness) to tailor packages over time in response to changing circumstances on the ground – a point addressed more fully in the Discussion in Chapter 8.

CHAPTER 8: Discussion and thesis conclusions

8.1 Summary of main findings and relationship to the wider literature

This thesis sought to enhance conceptual understanding and empirical analysis of health system resilience across a range of areas. These spanned shock conceptualisation, the empirical analysis of shock effects (with specific emphasis on compounding shocks) and system responses, and finally the identification of resilience strengthening measures – through the prism of a case study on vaccination delivery in Lebanon. Findings showed that while we might view each of the shocks in Lebanon – refugee arrivals from Syria, COVID-19 and the economic crisis – as exogenous from a system dynamics perspective, each interacted with existing system structures in a range of ways at different system levels to produce distinct effects.

Some common points of vulnerability within the vaccination delivery system were identifiable across shocks, many of them acting at facility level. These included variables such as facility level crowding, which appeared to drive down service uptake in and of itself but was also perceived as a proxy for quality of care. A key set of feedback loops was identified around uptake of vaccination through private clinics, linking changing demand patterns as household incomes fell, to mitigation measures introduced into the system to try to promote task-shifting to nurse-led vaccine administration. In addition, points of interaction between sequential shocks were identified that appeared to drive escalating risk in specific parts of the system as new shocks occurred. This was exemplified most clearly in the cold chain: the use of solar fridges, introduced to help mitigate cold chain vulnerabilities in the wake of Syrian refugee arrivals, proved problematic during the economic crisis as import restrictions made it harder to obtain spare parts to repair them. At the same time, the rising cost of fuel for generators, and decreasing reliability of mains electricity supplies in Lebanon meant that few practical, fallback options existed at facility level to maintain the cold chain.

A series of absorptive and adaptive measures were implemented to try to mitigate the effects of shocks on the vaccination delivery system, many operating at facility level. Absorptive measures included workload containment or redistribution (e.g., changing clinic hours during COVID-19), of the kind reported in work elsewhere looking at resilience in UNRWA systems in response to refugee movement (111,182), but also documented previously in Lebanon (281). Adaptive measures included medium-term activities to strengthen workforce skill-mix, and – importantly – task-shifting to promote nurse-led vaccination delivery, a move that depended for its success on a combination of [i] policy change at national level, [ii] the use of financial incentives to facilities, and [iii] a gradual, and then sudden, change in demand

behaviour among host communities who had historically preferred physician-administered vaccination in private clinics.

Attributes or capacities that seem to have been important for system responses in Lebanon were also identified, many corresponding with findings reported elsewhere in the literature, especially from socio-ecology (14,18,28,152). Decentralised funding streams were crucial in ensuring that vaccination delivery and other essential health services through PHCs were maintained. Facilities with implementing partner support had access to funds that helped them manage near-term changes in demand. Macro-level funding mobilisation, by contrast, took time. However, findings also suggested that the balance between centralised and distributed modes of working is not straightforward, notwithstanding the promotion of decentralisation in the wider resilience literature (168,170). On one hand, fragmentation in funding arrangements paradoxically enhanced near-term resilience to shocks. On the other, a concerted effort was underway during the data collection period to reinforce the norm-setting and oversight position of the MoPH vis-à-vis primary healthcare facilities across the public, third and private sectors, to support more equitable vaccination delivery over the long term. Findings in Chapter 7 underscored the critical importance of predictability in financing flows, and adequate human resourcing as inputs to effective resilience governance, reinforcing findings on critical resilience attributes reported elsewhere (18,28).

A key insight from Donella Meadows' work (see section 4.2.5) is that leverage points present positive opportunities for change within systems but are most often exposed when things go wrong. Table 15 maps leverage points identified across all the empirical studies in the thesis, spanning the vulnerabilities identified in Chapters 5 and 6 (including, for example, around human resourcing, funding flows, and time and material delays), with the points of action of key interventions (such as task-shifting at facility level, and policy change to reduce the cost of vaccination to refugees). This mapping shows that, while a range of leverage points were identified across the system, interventions focused predominantly at the level of events or system structures, and particularly around modification of parameters or constants in the system, and buffers. Although Meadows viewed interventions here as lower in impact than control system or mental model changes (248), interviewees for this research project repeatedly emphasised the transformative potential of appropriate human and financial resourcing for vaccination delivery.

No	Type of lever	Leverage point	Leverage points identified through the analysis	Example interventions by leverage point
12	Events or patterns of behaviour within the system	Constants or parameters within the system	<ul style="list-style-type: none"> Aggregate financial inputs into the system Number of vaccine doses available to administer through PHC network Number of clinic attendances for vaccination Cost of vaccination to service users (at facility level) 	<ul style="list-style-type: none"> Humanitarian response funding Procurement with UNICEF support to maintain supply at facility level at nominal cost to service users Multiple – spanning vaccination campaigns and SIAs, community engagement work, diversification of service access points including MHTs, others Policy change to reduce the cost of vaccination to service users through the PHC network
11	System structure(s) explaining events and patterns of behaviours	Buffers	<ul style="list-style-type: none"> Human resource availability at central (policy) and facility (doctors, nurses, managers) level Implementing partner funding to facilities 	<ul style="list-style-type: none"> (Temporary) donor funding of staff salaries; change in currency of payments to staff during the economic crisis Use of surge technical advisers Regular, contracted funding to maintain services, combined with surge funding to manage near-term demand increases (before donor response funding was mobilised)
10		Stock-and-flow structures	<ul style="list-style-type: none"> Physical infrastructure supporting the cold chain to facility level 	<ul style="list-style-type: none"> Introduction of solar fridges; cycling back of vaccine vials to district level when electricity supplies unreliable
9		The length of important time delays	<ul style="list-style-type: none"> Time to identification that a shock was unfolding Time to mobilisation of donor funding Time to distribution of vaccine doses from the national storage warehouse to facility level 	<ul style="list-style-type: none"> N/A Fast financial disbursement mechanisms Implementation of an electronic stock management system at the central warehouse in Karantina
8		The strength of balancing feedback loops	<ul style="list-style-type: none"> Loop linking PHC crowding to staff willingness to vaccinate and vaccination uptake during COVID-19 	<ul style="list-style-type: none"> Staff training in infection prevention and control; provision of PPE; patient flow measures including clinic cancellations or use of fixed appointment times
7		The strength of reinforcing loops	<ul style="list-style-type: none"> Loop linking nurse-led administration vaccine administration to vaccination uptake 	<ul style="list-style-type: none"> Financial incentives to PHC managers to promote nurse-led vaccination

				<ul style="list-style-type: none"> Community engagement work to increase service user trust in nurse-led vaccination
6	Information and controls systems influencing how the system works	The structure of information flows	<ul style="list-style-type: none"> Perception of changing demand for vaccination services at facility level (tracking of vaccination uptake) 	<ul style="list-style-type: none"> Introduction of new e-record systems to document uptake and facilitate identification of MOVs Use of outreach surveillance and GIS-based population mapping to target interventions
5		System rules	<ul style="list-style-type: none"> Norm-setting capability (legitimacy) of MoPH 	<ul style="list-style-type: none"> Financial and technical support from donors and agencies to procure vaccines for the EPI program Contracts between the MoPH and private providers to provide vaccines at nominal cost and report uptake in exchange for free doses
4		Self-organisation	<ul style="list-style-type: none"> Parallel service pathways to maximise opportunities for access to vaccination 	<ul style="list-style-type: none"> Selective use of MMUs, opening of border crossing sites Service integration
3	Mental models (values, beliefs and assumptions) that govern how the system works	System goals	<ul style="list-style-type: none"> Importance attached to vaccination vis-à-vis other strategic priorities for health actors Strategic orientation regarding the inclusion of refugees as a target population for vaccination through the PHC network 	<ul style="list-style-type: none"> LCRP and MoPH strategy documents underscoring the prioritisation of vaccination Policy change to open PHCs as a common access point for Syrian refugees and host communities, for vaccination at nominal charge
2		The paradigm out of which the system arises	N/A	N/A
1		Transcending paradigms	N/A	N/A

Table 15. Mapping system leverage points identified through the thesis against purposeful interventions implemented to support vaccination delivery in Lebanon since 2012.

For reasons of space this table is indicative rather than comprehensive. Further details can be found in Chapters 5, 6 and 7.

Notable intervention gaps – partly because these reflect some of the most politicised aspects of the response to the shocks Lebanon has faced – concern time delays in shock recognition, and for funding mobilisation. Findings presented here also reiterate observations in other disciplines regarding the synergistic effect of interventions addressing one leverage point on the success of those in others (367): task-shifting likely would not have been successful without supporting financial incentives from implementing partners, and the demand shock to the private sector following the economic crisis also contributed heavily.

8.2 Contributions of the thesis

This thesis set out to make contributions in three main areas (see section 1.7):

1. Conceptual: improving understanding of system shocks, and of how sequential or overlapping shocks may interact with one another to influence risk; understanding of resilience in health systems in general, and vaccination delivery systems in particular, in the context of protracted humanitarian crises;
2. Methodological: the application of system dynamics modelling to the study of resilience in vaccination delivery systems;
3. Policy: identifying approaches to bolstering resilience in childhood vaccination delivery, whether through formal (programmatic) interventions, or through action on critical system leverage points.

In this section, I discuss key insights from the analyses presented in preceding chapters, as they relate to these areas.

8.2.1 Conceptual contributions

8.2.2.1 Theorising shocks

This thesis has shown that shocks – in themselves diverse – can produce very varied and sometimes unexpected effects within vaccination delivery systems. The use of CLDs in Chapter 5 showed that some of these variations could be linked to time and material delays (e.g., in recognition of an unfolding crisis, and in the mobilisation of response funding), but that many stemmed from the range of leverage points within the system on which a particular exogenous shock acted. The economic crisis was, in this sense, qualitatively different from the others considered in this thesis in the extent of its impact, because it concurrently affected both demand- and supply-side structures.

It is, to my knowledge, the first study to systematically analyse the effects of compound shocks, and the ways in which these may give rise to cascading risks within health systems (in this case, vaccination delivery systems). Results in Chapters 6 and 7 show how shock interactions in Lebanon amplified vulnerabilities in specific parts of the vaccination delivery

system, but also created opportunities for transformational change. This was exemplified by the facilitating effect the economic crisis was beginning to have for governance transformation with respect to private providers, following policy changes initially implemented in the wake of refugee arrivals. Further interrogation of the interactions between multiple shocks on different services, and in different contexts, should be a priority both for academic researchers and practitioners seeking to strengthen risk assessment and preparedness approaches for health systems.

8.2.2.2 Theories of system resilience

Attributes or capacities of resilient systems

This thesis makes a series of original contributions to our understanding of resilience in vaccination delivery systems, and to health systems more widely. Important insights emerge regarding attributes or system characteristics that seem to support or undermine resilience over time. Firstly, the wider health systems literature – drawing particularly on organisational theory – shows that resilience is usually seen to depend on availability of collateral pathways (i.e., parallel pathways that might not see extensive use under normal conditions but can be mobilised to provide surge capacity in the event of a shock) (18). This is reinforced by observations from Lebanon, although findings reported in this thesis imply that redundancies in specific areas are particularly important. For example, findings in Chapter 5 show that the availability of multiple funding lines to health facilities proved especially important for the continuation of local level service delivery particularly as the economic crisis in Lebanon worsened. Maintenance of essential services probably would not have been possible had these facilities drawn a majority of their funding from the MoPH, given the budget constraints imposed on the Ministry from 2017 onwards. Similarly, findings in Chapter 6 illustrate the importance of strengthened information exchange across the vaccination delivery system over time, and how better integration of these systems contributed to more effective identification of missed opportunities for vaccination.

Similarly, diversity emerges as a strong theme, but not perhaps in ways typically expected. A core part of the critique of the health sector in Lebanon historically has been that it is fragmented, that this contributes to burden-shifting onto service users and accentuates transaction costs for service providers (206). In the face of the shocks described in this thesis, however, it was precisely this pluralism (in funding lines, in the range of implementing partners, donors and other actors involved in vaccination delivery) that provided a buffer against some of the worst effects of the shocks, especially the economic crisis, on service delivery (368).

System responses to shocks: transformative change

While studies elsewhere have documented absorptive and adaptive changes in health systems in response to shocks (11,12), a novel feature of this thesis was in showing how shocks can create moments of opportunity which can be used to drive system transformation. Successive shocks in Lebanon have been used by the MoPH, with donor support, to bring about rapid expansion of the PHC network, and, through publicising the availability of vaccination free of charge in this network, to drive movement of service users from the private to public sectors. As Chapter 5 shows, strategies were used at multiple system levels to reinforce this change. Nationally, UNICEF provided procurement support to the MoPH to ensure a consistent supply of vaccine doses that could be distributed to PHCs and private providers who agreed to deliver vaccines free of charge. There were national level policy changes to promote PHC network expansion, and to facilitate cooperative agreements with private providers. At facility level, service providers worked to draw service users in for vaccination if they attended for other reasons (e.g., to obtain chronic disease medications, which are increasingly scarce in Lebanon now). What was perhaps especially significant about the change in private provider behaviour was that the original policy directive permitting agreements between the MoPH and private clinics was put in place in 2015, but it was not until the economic crisis that it gained any meaningful traction on the ground. These changes may, if funding and political commitment can be preserved, lead to a positive and transformative change in service delivery, and better access, for the long-term.

To the best of my knowledge, this thesis is the first to use system dynamics to show how health system transformations can occur in response to a shock in a humanitarian setting. We found evidence indicating transformative change in a number of areas but particularly around task-shifting for service delivery, the recruitment of private clinics to support routine vaccination delivery at nominal cost, and efforts to build the institutional legitimacy of the MoPH as a norm-setter. The first two of these changes gave rise to wholly new system structures – although these changes were seen as meso- and micro-level rather than at national level. By contrast, work to bolster the MoPH's norm-setting power was national in scope with the potential to drive whole system transformation, although at the time of writing it was too early to say how far this experiment would progress. Although analyses of governance transformation in health systems have been published previously, these have been in stable settings and have tended to focus on the implementation of reform programmes – health service decentralisation in Kenya, for example (369–371) – rather than describing shock responses as part of a broader analysis of system resilience. As the review in chapter 2 showed, empirical studies of system transformation in the wider literature on resilience are also in short supply.

8.2.2 Methodological contributions

A key methodological contribution of this thesis has been in the application of system dynamics to the study of resilience in vaccination delivery systems in humanitarian settings. A handful of studies have considered the role of specific factors e.g., trust in influencing vaccination uptake in stable settings (63), and trade-offs in service delivery between vaccination and other domains e.g. maternal health in humanitarian contexts including Afghanistan (81) by applying system dynamics. However, none of these studies have explicitly considered system vulnerabilities and resilience; none have considered in detail the effects of shocks on the systems in question; and none have used SDM to consider the impact of compounding shocks, as performed here.

As 'proof of concept', the material presented in Chapter 5 in particular illustrates that analysing shocks and system responses using system dynamics, and more specifically using a purposive text analysis approach, in these settings is feasible, and that it can produce important inferences regarding causal drivers of system behaviours. The holistic view of causal drivers influencing system responses that was provided by the CLDs offered important advantages over other qualitative approaches which might clarify particular aspects, but could not provide a whole-system view.

However, experiences in performing system dynamics using purposive text analysis demonstrated that it is labour-intensive and that findings take time to derive. A GMB-based approach has been used to support health systems work in humanitarian contexts previously including Lebanon (110,111,251,372). This approach could have helped reduce the labour intensity of CLD development and validation, but GMB was not used in this thesis because of concerns regarding the extent to which complex power relations between actors in Lebanon could be managed in a group context – particularly the extent to which it would be possible to give voice to perspectives from the ground. Successful deployments of GMB in other humanitarian settings have tended to involve engagement with stakeholders from a single organisation (albeit at multiple levels) (111), or to more narrowly defined stakeholder groups (251). This suggests a tension in performing qualitative system dynamics work especially in humanitarian contexts where resources are often short, and decisions need to be made quickly. On one hand, purposive text analysis offers strong methodological rigour and better ability to manage stakeholder relations but is labour and time intensive. On the other hand, GMB demands strong group facilitation skills to counteract potentially adverse power dynamics, but results are more immediately derived.

8.2.3 Contributions to policy development and implementation

8.2.3.1 Approaches to resilience assessment and measurement

Although this was not an explicit focus of the research reported in this thesis, a number of insights emerge that are nevertheless relevant to resilience assessment and measurement. Firstly, empirical analyses in Chapters 5 and 6 pointed to domains potentially amenable to measurement as early warning indicators for system vulnerability. Stability in human resourcing emerges as a consistently important factor in explaining system resilience (or the absence thereof) irrespective of the shock. Profound difficulties arose at policy and service delivery levels in Lebanon because of human resource attrition. This was especially pronounced as the financial crisis took hold. Human resourcing problems were linked to a central government hiring freeze, to changes in donor policy concerning the extent to which they were willing to pay for staff salaries, and to health worker emigration as salaries rapidly devalued from 2020 to 2022. Similarly, stability in financial inputs was widely viewed as critical. An important critique emerged from interviews of increasing short-termism in donor funding and progressively shorter project cycle lengths. This reduced the capacity and capability of implementing partners to adequately respond to service needs on the ground over time. These findings suggest that trends in human resource availability, distribution and metrics for key stocks and flows at facility level are likely to provide good early warning indicators for system resilience.

Findings in Chapter 5 also identified a series of delays acting as bottlenecks influencing speed of response on a system level – some of which may be amenable to measurement. At macro-level, times from funding donor funding mobilisation to deployment to facility level, and time to distribution of vaccine doses to key junction points in the cold chain are both likely to be important indicators of system responsiveness.

More broadly, the application of system dynamics in Chapter 6 showed that in-depth analysis to model out cause and effect relationships in systems can provide valuable insights regarding system behaviours in response to shocks that might not otherwise be available to system stakeholders.

8.2.3.2 Bolstering vaccination delivery system resilience in humanitarian settings in general, and in Lebanon specifically

Findings across Chapters 5, 6 and 7 provide important policy and practice insights regarding resilience-promoting strategies for vaccination delivery systems in general, and Lebanon in particular. The first and most important insight is that there is no “silver bullet” solution and that resilience promotion likely depends on multi-component packages of support, the precise composition of which will need to be modified over time in response to emerging needs.

However, findings also point to a series of recommendations for the consideration of specific stakeholder groups:

Stakeholder group	Recommendation
Lebanese government	<ul style="list-style-type: none"> • Consider permitting further, targeted extensions to current use of MMUs, with implementing partner support, to increase uptake among low coverage populations; • Explore opportunities for integration of services in the PHC network with other essential services (in health and other domains) to maximise opportunities for vaccination uptake; • Work with implementing partners to introduce, and where relevant expand the use of, community mobilisers recruited from within low coverage host communities, refugee and migrant populations;
Donors and technical agencies	<ul style="list-style-type: none"> • Explore flexible approaches to financing and contracting with partners in Lebanon to allow space for longer-term, strategic approaches to maximising vaccination uptake; • Consider temporarily reinstating salary support for human resourcing in critical positions in the vaccination delivery system to combat staff attrition;
Implementing partner organisations	<ul style="list-style-type: none"> • Lobby for increased financial allocations from donors to support strengthened resilience in the vaccination delivery system; • Perform (or where relevant publish the results of existing) evaluations of pay-for-performance and other incentivisation interventions to determine the extent to which different models have improved coverage for key vaccinations;
Academic and policy researchers	<ul style="list-style-type: none"> • Generate and disseminate evidence on different intervention portfolio designs, and ways in which these may be tailored for use at different levels in the vaccination delivery system in Lebanon.

Table 16. Policy recommendations to key stakeholder groups arising from the research findings.

8.3 Limitations of the thesis

In this section, I focus on general limitations of the research project as a whole. Limitations specific to each individual study are addressed in more detail in the relevant chapters.

8.3.1 Conceptual limitations

Limitations of the research project are both conceptual and methodological. From a conceptual perspective, one important limitation is the application of a national lens in defining the boundaries of the system for analysis – although the empirical studies in chapters 5 and 6 explicitly considered dynamics at multiple system levels (sub-nationally). The challenges of boundary definition have long been recognised in the wider literature on systems thinking (373–376). There has been much discussion in the health systems literature of the limitations of using nationally-defined analytic boundaries when so many contemporary health systems problems are influenced by dynamics at multiple levels – from local through to supra-national

(24,39). In some respects, this thesis reinforces these by focusing on the Lebanese vaccination delivery system as defined in national terms. One important hallmark of the Lebanese context – pointed out by a number of interviewees – which mitigates against this limitation, is the small size of the country meaning that while regional and local dynamics do influence health service delivery in important ways, this effect is not as dramatic as is seen in other, larger (and administratively more complex) contexts.

Steps were also taken through the design and delivery of the research project to address this limitation. A scoping study was performed to clarify the most appropriate boundary definition to apply – and confirmed a stakeholder preference for a primarily national view. Purposive sampling of interviewees included a subset working for international donor organisations, and many of the implementing partner representatives worked for organisations with an international footprint. This enabled critical engagement with transnational factors shaping service delivery including the speed of crisis recognition, of donor funding mobilisation, and issues around the procurement and shipment of vaccines, for example. Interviewees were also recruited at regional and local level in two areas of Lebanon to try to capture dynamics at these levels. Finally, an explicit goal of the qualitative study was to address questions concerning the influence of transnational relations on governance approaches for vaccination delivery in Lebanon, to complement the bounded analysis presented in Chapter 5.

Conceptual limitations extend to subject coverage in the findings. For example, there was a surprising lack of discussion of the role of corruption in influencing system resilience by participants, especially in the qualitative study reported in Chapter 6, although wider health systems work makes clear the impact this can have on system performance (377,378). Although some probing around the role of corruption was attempted through the stakeholder interviews, little material was elicited. While it is possible that this was because interviewees did not feel corruption played an important role in driving system resilience, more likely explanations include [i] concerns over professional exposure despite our assertion that all data gathered would be treated in confidence, [ii] the “taboo” nature of discussions around corruption (although it is increasingly acknowledged in Lebanon, especially since 2019), and [iii] the difficulty of building relationships and trust with participants in the context of primary data collection conducted largely remotely via Zoom (see section 8.3.3).

A gap that is more difficult to explain concerns the Beirut blast of August 2020 – both as a discrete system shock, and as a trigger point for resilience-promoting system responses. The blast featured much less prominently in the CLDs in Chapter 5, and the governance material covered in Chapter 6, than other shocks. Interview data indicated this may have been partly because vaccine doses held at the national warehouse in Karantina were relocated to cold

storage at the Rafiq Hariri University Hospital within 24 hours and so practical effects on the supply chain were limited. Impact on service delivery also appears to have been relatively contained within greater Beirut. Finally, while interview and other data sources confirm that substantial relief funding mobilisation did occur in response to the blast, this was not explicitly targeted to vaccination delivery. Resources for this continued to be drawn primarily via existing funding channels under the LCRP.

A final, general, conceptual limitation of this thesis concerns the generalisability of findings. This thesis was built around an in-depth case study in a single setting – Lebanon – with specific contextual features, and around a specific essential health service as a cipher (childhood vaccination). A key theme throughout the thesis concerns the importance of due attention to context in understanding the effects that shocks give rise to (explored through chapters 5, 6 and 7). The particular confluence of shocks in Lebanon was globally unusual. While this made it a very good environment in which to study system resilience, there are natural limitations to the extent to which findings can be generalised to other settings, where health system and service delivery arrangements may look very different. The question of the extent to which findings can be generalised beyond Lebanon is one that I am exploring currently through follow-on work as part of this research project in Uganda (a country that has also experienced large-scale population displacement, and a COVID-19-related shock in recent years). It is an area that merits wider conceptual and methodological consideration by health systems researchers more generally.

A related set of questions concerns the generalisability of findings to other service domains. On this, insights from the wider literature are encouraging. The discussion in section 8.1 notes clear points of commonality between findings regarding resilience attributes and leverage points identified in this analysis, with those observed in other work in humanitarian settings applied to service areas as diverse as non-communicable disease prevention and control and mental health service provision (111,182,250), as well as from work on system resilience in stable contexts (11,12,14).

8.3.2 Methodological limitations

A number of methodological limitations can be identified – many discussed in more detail in Chapters 5 and 6. Important limitations were imposed by the timing of the analysis. As Chapter 3 makes clear, the operational environment in Lebanon has been very volatile especially over the past two years. The analysis presented in this thesis addresses a number of system-level exposures (the shocks) interrelationships between which are complex and still evolving. This made disentangling causal drivers of system behaviour in Chapter 5 challenging. In addition, data collection occurred during a window in which system behaviours in response to the first

shock (the refugee movement) had settled to some degree, but those in response to COVID-19 and the economic crisis were still unfolding. This introduced a risk of recall bias in relation to the refugee movement, which I tried to address by probing for information specifically around interviewees' lived experiences, and by emphasising the need for them to highlight areas where their recollection was uncertain. In relation to COVID-19 and the economic crisis, conditions on the ground evolved so quickly during the period in which wave 2 interviews were carried out that participants' evolving perspectives may not have been fully captured. Similarly, the February 2022 cut-off for interviews imposed a somewhat artificial endpoint to data collection at a time when system responses were continuing to develop. On the other hand, saturation testing through the CLD development and qualitative analysis reported in Chapters 5 and 6 suggests a good level of agreement between interviewees on key shock effects and system responses during this period.

Selection bias is always a risk in qualitative interviewing. Purposive sampling can be a helpful strategy in ensuring coverage across the most relevant stakeholder groups, but naturally cannot capture the full spectrum of potential perspectives. Two specific shortcomings for this analysis were that it was not possible to sample a broad cross-section of interviewees from the private sector (noting its historically important role in vaccination delivery), and there were no participants from the MoSA's SDC network. These limitations were partly offset by the boundary definition for the analysis, emphasising dynamics relating to the PHC network. In addition, the explicit goal of purposive sampling is not to select a statistically representative sample, but rather to gather as full a range of perspectives as possible within the time and resource limitations of a defined research project. The use of saturation testing (both in the form of variable, link, delay and feedback loop tracking during CLD development in Chapter 5 – see **Appendix 7** – and in the thematic analysis reported in Chapter 6) was central in ensuring that data collection was brought to a halt only when new variables, causal links or themes ceased to emerge.

A related limitation concerns the absence of a formal service user perspective. This was instead assumed by proxy, by interviewing those involved in frontline service delivery and probing their knowledge of service user behaviours. However, their reflections may not have accurately captured the true range of service user perspectives across populations, especially as these evolved over time. The decision to limit the focus of analysis to perspectives from those involved in vaccination supply was a pragmatic one given the time and resource constraints to the research project this thesis describes, but one that future work should look to address. This is particularly important given an emerging focus on community perspectives on health system resilience particularly in response to climatic shocks (269,270), and given

what we know about the diversity of population needs and health seeking behaviours in Lebanon (206,214,379).

Finally, this thesis reports insights derived from qualitative system dynamics only. The absence of quantitative, simulation modelling imposes important limitations to what can be said about dynamic behaviour within the system. As David Lane has highlighted, causal mapping has representational limitations, and can only be used to *infer* behaviour, whereas formal simulation modelling *deduces* this behaviour in quantitative terms (380). More specifically, CLDs can obscure potentially important dynamics by not incorporating stock-flow relationships. Formal findings in these areas can be gleaned only from quantitative modelling (381). This is a deficit that I am addressing in follow-on work, to develop a simulation model for Lebanon based on the CLD reported in Chapter 5.

8.3.3 Reflexivity

Some limitations to this work derive from my own position as lead researcher. As a qualified medical doctor with experience working on vaccination policy in the context of the COVID-19 response, I was able to relate professionally to many of the participants in the study and the topic under investigation. I also had some knowledge of the operating context in Lebanon and of issues relating to health service provision for Syrian refugees before starting this research project, from past research work with partners in-country including at AUB (235,236,382). Finally, I was able to draw on a mixed British-Egyptian heritage and extensive past experience living and working the wider Middle East, and to some degree on knowledge of Arabic, in supporting the fieldwork for the project, although a majority of interviews were carried out in English. This helped to build rapport with participants.

However, I was also in a number of respects identifiably an 'outsider' to interviewees, most obviously as a researcher based at a British university. This – and the source of funding for the work – required careful explanation before each interview. Secondly, relevant service experience before starting the project derived almost entirely from the UK, and from previous work with a large international donor organisation, rather than on-the-ground delivery in Lebanon. Thirdly, limitations to my knowledge of the dialect of Arabic in Lebanon sometimes made fluency in interviews challenging.

Finally, and importantly, a perception of 'outsider' status is likely to have been exacerbated by disruptions to the research project because of COVID-19. The pandemic imposed major constraints on what was possible in terms of field data collection on the ground in Lebanon and necessitated a substantial re-design of the research project. The unexpected need to shift to remote data collection partway through the project naturally limited the extent to which it was possible to build rapport with study participants, and greatly reduced opportunities for

'soft' information gathering around the work to help contextualise findings (e.g., through compiling field notes).

These factors all contributed to challenges in engaging stakeholders for the project but were partly offset in three ways. Firstly, the Primary Healthcare Department at the MoPH was supportive throughout the project and included a formal letter of introduction to PHCs in the network to aid recruitment. Secondly, I worked closely with an in-country co-investigator based at AUB who was known to a number of the participants. Thirdly, I was fortunate to have support from a Lebanese research assistant to help address this barrier in the few interviews carried out entirely in Arabic.

Outsider status may have contributed to challenges in data collection in specific areas of the research project. For example, while engagement from national and regional level stakeholders (many of whom worked for international NGOs and technical agencies) was generally good, interviews with facility-level actors proved far harder to secure. This may, however, simply have reflected day-to-day challenges many facilities were facing at the time I was carrying out data collection. A second area concerned discussion of politically contentious topics. For instance, there is a large literature from Lebanon on the role of confessional politics in determining allocation of health resources (206,383–386). Despite probing around this topic, few interviewees addressed it. This may have been because they did not believe that it played a significant role in vaccination delivery. A more likely explanation, however, was insufficient interviewer-interviewee rapport. As highlighted above, corruption was also rarely addressed although evidence suggests it plays an important role in shaping service delivery in many settings (377,378).

8.4 Directions for future research

Findings reported in this thesis suggest some immediate areas for onward investigation, some of which are already in progress. Section 8.3.1 highlighted concerns over the generalisability of findings, which may be partly addressed by a supplementary case study linked to this research project which is being carried out in Uganda. Section 8.3.2 also highlighted a need to formally test findings using simulation modelling – for which a quantitative system dynamics model for Lebanon is currently under development. These investigations should help to address some of the limitations to the thesis identified above.

Findings reported here also point to a wide range of areas for further research – broadly aligning with each of the objectives. The analysis of shocks and their effects presented in this thesis is novel but naturally focuses on a single case study. There is ample scope for

comparative work to investigate the differential effects of comparable shocks (perhaps classified according to the broad type of event – e.g., climatic, conflict-related – or scope of impact) in different settings. Further work might also consider the mediating effects of context and different system architectures and governance arrangements on system behaviour. There is enormous potential for further examination of compound shock effects especially in humanitarian settings (complex crises, for example). The application of system dynamics for this purpose in this thesis has shown promise and may help to inform more rigorous approaches to risk assessment for health systems facing compound shocks in future.

A key area for further development – especially for practitioners – concerns resilience assessment and measurement. Section 8.3.2.1 highlighted some of the domains in which findings from this thesis might support the development of resilience measures. Future work following on from this thesis to develop a quantitative simulation model may support indicator development, as well identifying patterns of behaviour to look for, for monitoring purposes. The urgency of further research in the area of resilience assessment and measurement for health systems is now widely acknowledged (14,19,387), and one where insights from other disciplines are again likely to be critical (155).

A further gap concerns community perspectives on health systems resilience, and the way(s) in which these are integrated into meso- and macro-level work of the kind reported here. As noted in section 8.3.2, the decision not to interview service users was a pragmatic one given time and resource constraints. Diversity across displaced and host community populations in Lebanon is also considerable, introducing challenges for robust sampling. In general, the pool of work addressing community perspectives on health systems resilience is limited (269,270), reflecting a wider criticism of health system resilience activities that have appeared to overlook the importance of communities and trust (388).

Finally, from a methodological perspective, important questions remain best approaches in humanitarian settings. This thesis has shown the potential value of system dynamics in exploring health system resilience in humanitarian settings but emphasised the labour intensity of using a purposive text analysis approach. Findings reported here also do not address the critical question of research translation. CLDs are hard to communicate to non-specialist audiences. There is an urgent need for further work to interrogate which methods offer clearest value for decision-makers seeking to improve system resilience in humanitarian settings given the combination of resource, security and time pressures they face.

8.5 Concluding remarks

At the time of writing, economic and social conditions in Lebanon continue to deteriorate rapidly. The recent deaths of 89 people following the sinking of a boat carrying migrants from the country seemingly bound for Syria (389), exemplify the struggle for everyday existence for people living in Lebanon, of which equitable access to preventive health services is just one dimension. For those living through the shocks described in this thesis, the weight of language should not be underestimated. As one interviewee for this research project put it:

“I started to get annoyed by the word resilience...at one point of time, resilience was a positive term in the Lebanese context. Now you are getting your knocks on the head in more frequent situations that you are no longer able to experience recovery in a way. This is only human, we cannot be supermen and women – after you get 2, 3, 4, 5 knocks same day or some moment, it is no more resilience it is either you die or you don't die, it is survivorship” [LFS12, government official]

This is a salutary reminder to health system researchers that our work should be grounded, always, in a practical commitment to moving beyond theory, to improve the lives of the research participants with whom we work, and the communities in which they live.

REFERENCES

1. Ridde V, Lechat L, Meda IB. Terrorist attack of 15 January 2016 in Ouagadougou: How resilient was Burkina Faso's health system? *BMJ Global Health*. 2016;1(1): 1–7. <https://doi.org/10.1136/bmjgh-2016-000056>.
2. Hanefeld J, Mayhew S, Legido-Quigley H, Martineau F, Karanikolos M, Blanchet K, et al. Towards an understanding of resilience: responding to health systems shocks. *Health Policy and Planning*. 2018;33(3): 355–367. <https://doi.org/10.1093/heapol/czx183>.
3. Kruk ME, Ling EJ, Bitton A, Cammett M, Cavanaugh K, Chopra M, et al. Building resilient health systems: a proposal for a resilience index. *BMJ*. 2017;357: j2323. <https://doi.org/10.1136/bmj.j2323>.
4. Kieny M paule, Evans DB, Schmets G, Kadandale S. Health-system resilience: reflections on the Ebola crisis in western Africa. *Bulletin of the World Health Organization*. 2014;92(12): 850–850. <https://doi.org/10.2471/BLT.14.149278>.
5. Gilson L, Barasa E, Nxumalo N, Cleary S, Goudge J, Molyneux S, et al. Everyday resilience in district health systems: emerging insights from the front lines in Kenya and South Africa. *BMJ Global Health*. 2017;2(2): e000224. <https://doi.org/10.1136/BMJGH-2016-000224>.
6. Gilson L, Ellokori S, Lehmann U, Brady L. Organizational change and everyday health system resilience: Lessons from Cape Town, South Africa. *Social Science & Medicine*. 2020;266(October): 113407. <https://doi.org/10.1016/j.socscimed.2020.113407>.
7. Haldane V, de Foo C, Abdalla SM, Jung AS, Tan M, Wu S, et al. Health systems resilience in managing the COVID-19 pandemic: lessons from 28 countries. *Nature Medicine*. 2021;27(6): 964–980. <https://doi.org/10.1038/s41591-021-01381-y>.
8. Greer S, King E, Massard da Fonseca E, Peralta-Santos A. *Coronavirus Politics*. Coronavirus Politics. Ann Arbor, MI: University of Michigan Press; 2021. <https://doi.org/10.3998/mpub.11927713>.
9. Turenne CP, Gautier L, Degroote S, Guillard E, Chabrol F, Ridde V. Conceptual analysis of health systems resilience: A scoping review. *Social Science & Medicine*. 2019;232: 168–180. <https://doi.org/10.1016/J.SOCSCIMED.2019.04.020>.
10. Blanchet K, Nam SL, Ramalingam B, Pozo-Martin F. Governance and capacity to manage resilience of health systems: Towards a new conceptual framework. *International Journal of Health Policy and Management*. 2017;6(8): 431–435. <https://doi.org/10.15171/ijhpm.2017.36>.
11. Biddle L, Wahedi K, Bozorgmehr K. Health system resilience: a literature review of empirical research. *Health Policy and Planning*. 2020;(June): 1084–1109. <https://doi.org/10.1093/heapol/czaa032>.
12. Fridell M, Edwin S, Schreeb J von, Saulnier DD. Health system resilience: what are we talking about? A scoping review mapping characteristics and keywords. *International Journal of Health Policy and Management*. 2020;9(1): 6–16. <https://doi.org/10.15171/ijhpm.2019.71>.
13. Harmer A, Macrae J. *Beyond the continuum: The changing role of aid in protracted crises*. HPG Research Report ODI. London: Overseas Development Institute; 2004. <https://odi.org/en/publications/beyond-the-continuum-the-changing-role-of-aid-policy-in-protracted-crises-2/> [Accessed 1st December 2022].
14. Thomas S, Sagan A, Larkin J, Cylus J, Figueras J, Karanikolos M. *Strengthening health systems resilience: Key concepts and strategies*. Copenhagen: WHO Regional Office for Europe; 2020. <https://apps.who.int/iris/handle/10665/332441> [Accessed 1st December 2022].
15. Keegan C, Thomas S, Normand C, Portela C. Measuring recession severity and its impact on healthcare expenditure. *International Journal of Health Care Finance and Economics*. 2013;13(2): 139–155. <https://doi.org/10.1007/s10754-012-9121-2>.
16. Kappes MS, Keiler M, von Elverfeldt K, Glade T. Challenges of analyzing multi-hazard risk: A review. *Natural Hazards*. 2012;64(2): 1925–1958. <https://doi.org/10.1007/s11069-012-0294-2>.
17. Gill JC, Malamud BD. Anthropogenic processes, natural hazards, and interactions in a multi-hazard framework. *Earth-Science Reviews*. 2017;166: 246–269. <https://doi.org/10.1016/j.earscirev.2017.01.002>.

18. Barasa E, Mbau R, Gilson L. What Is Resilience and How Can It Be Nurtured? A Systematic Review of Empirical Literature on Organizational Resilience. *International Journal of Health Policy and Management*. 2018;7(6): 491–503. <https://doi.org/10.15171/ijhpm.2018.06>.
19. Saulnier DD, Blanchet K, Canila C, Muñoz DC, Zennaro LD, Savigny D de, et al. A health systems resilience research agenda : moving from concept to practice. *BMJ Global Health*. 2021;6: 1–5. <https://doi.org/10.1136/bmjgh-2021-006779>.
20. Forsgren L, Tediosi F, Blanchet K, Saulnier DD. Health systems resilience in practice: a scoping review to identify strategies for building resilience. *BMC Health Services Research*. 2022;22(1): 1173. <https://doi.org/10.1186/s12913-022-08544-8>.
21. Chee G, Pielemeier N, Lion A, Connor C. Why differentiating between health system support and health system strengthening is needed. *The International Journal of Health Planning and Management*. 2013;28(1): 85–94. <https://doi.org/10.1002/hpm.2122>.
22. Witter S, Pavignani E. *Review of Global Fund Investments in Resilient and Sustainable Systems for Health in Challenging Operating Environments*. 2016. <https://doi.org/10.13140/RG.2.2.33241.93281>.
23. Foroughi Z, Ebrahimi P, Aryankhesal A, Maleki M, Yazdani S. Toward a theory-led meta-framework for implementing health system resilience analysis studies: a systematic review and critical interpretive synthesis. *BMC Public Health*. 2022;22(1): 1–13. <https://doi.org/10.1186/s12889-022-12496-3>.
24. Wernli D, Clausin M, Antulov-Fantulin N, Berezowski J, Biller N, Blanchet K, et al. Building a multisystemic understanding of societal resilience to the COVID-19 pandemic. *BMJ Global Health*. 2021;6(7): e006794. <https://doi.org/10.1136/bmjgh-2021-006794>.
25. Folke C. Resilience (Republished). *Ecology and Society*. 2016;21(4): art44. <https://doi.org/10.5751/ES-09088-210444>.
26. Walker B, Holling CS, Carpenter SR, Kinzig AP. Resilience, Adaptability and Transformability in Social-ecological Systems. *Ecology and Society*. 2004;9(2): art5. <https://doi.org/10.5751/ES-00650-090205>.
27. Elmqvist T, Andersson E, Frantzeskaki N, McPhearson T, Olsson P, Gaffney O, et al. Sustainability and resilience for transformation in the urban century. *Nature Sustainability*. 2019;2(4): 267–273. <https://doi.org/10.1038/s41893-019-0250-1>.
28. Ismail SA, Bell S, Chalabi Z, Fouad FM, Mechler R, Tomoiaia-Cotisel A, et al. Conceptualising and assessing health system resilience to shocks: a cross-disciplinary view. *Wellcome Open Research*. 2022;7(May): 151. <https://doi.org/10.12688/wellcomeopenres.17834.1>.
29. Fraccascia L, Giannoccaro I, Albino V. Resilience of Complex Systems: State of the Art and Directions for Future Research. *Complexity*. 2018;2018: 1–44. <https://doi.org/10.1155/2018/3421529>.
30. Xu L, Kajikawa Y. An integrated framework for resilience research: a systematic review based on citation network analysis. *Sustainability Science*. 2018;13(1): 235–254. <https://doi.org/10.1007/s11625-017-0487-4>.
31. Ngo TM, Rogers B, Patnaik R, Jambai A, Sharkey AB. The Effect of Ebola Virus Disease on Maternal and Child Health Services and Child Mortality in Sierra Leone, 2014–2015: Implications for COVID-19. *The American Journal of Tropical Medicine and Hygiene*. 2021;104(3): 1085–1092. <https://doi.org/10.4269/ajtmh.20-0446>.
32. Jawad M, Hone T, Vamos EP, Cetorelli V, Millett C. Implications of armed conflict for maternal and child health: A regression analysis of data from 181 countries for 2000–2019. Bhutta ZA (ed.) *PLOS Medicine*. 2021;18(9): e1003810. <https://doi.org/10.1371/journal.pmed.1003810>.
33. Jawad M, Hone T, Vamos EP, Roderick P, Sullivan R, Millett C. Estimating indirect mortality impacts of armed conflict in civilian populations: Panel regression analyses of 193 countries, 1990–2017. *BMC Medicine*. 2020;18(1): 1–11. <https://doi.org/10.1186/s12916-020-01708-5>.
34. Young H, Borrel A, Holland D, Salama P. Public nutrition in complex emergencies. *The Lancet*. 2004;364(9448): 1899–1909. [https://doi.org/10.1016/S0140-6736\(04\)17447-3](https://doi.org/10.1016/S0140-6736(04)17447-3).
35. Checchi F, Gayer M, Grais RF, Mills EJ. *Public health in crisis-affected populations: A practical guide for decision-makers*. London: Overseas Development Institute; 2007. <https://odihpn.org/publication/public->

- health-in-crisis-affected-populations-a-practical-guide-for-decision-makers/ [Accessed 1st December 2022].
36. Heudtlass P, Speybroeck N, Guha-Sapir D. Excess mortality in refugees, internally displaced persons and resident populations in complex humanitarian emergencies (1998-2012) - Insights from operational data. *Conflict and Health*. 2016;10(1): 15. <https://doi.org/10.1186/s13031-016-0082-9>.
 37. Singh NS, Atallahjan A, Ndiaye K, Das JK, Wise PH, Altare C, et al. Delivering health interventions to women, children, and adolescents in conflict settings: what have we learned from ten country case studies? *The Lancet*. 2021;397(10273): 533–542. [https://doi.org/10.1016/S0140-6736\(21\)00132-X](https://doi.org/10.1016/S0140-6736(21)00132-X).
 38. Moon S, Sridhar D, Pate MA, Jha AK, Clinton C, Delaunay S, et al. Will Ebola change the game? Ten essential reforms before the next pandemic. The report of the Harvard-LSHTM Independent Panel on the Global Response to Ebola. *The Lancet*. 2015;386(10009): 2204–2221. [https://doi.org/10.1016/S0140-6736\(15\)00946-0](https://doi.org/10.1016/S0140-6736(15)00946-0).
 39. Gostin LO, Tomori O, Wibulpolprasert S, Jha AK, Frenk J, Moon S, et al. Toward a Common Secure Future: Four Global Commissions in the Wake of Ebola. *PLoS Medicine*. 2016;13(5): 1–15. <https://doi.org/10.1371/journal.pmed.1002042>.
 40. Hilhorst D. Classical humanitarianism and resilience humanitarianism: making sense of two brands of humanitarian action. *Journal of International Humanitarian Action*. 2018;3(1): 15. <https://doi.org/10.1186/s41018-018-0043-6>.
 41. World Health Organization. *Position paper: building health systems resilience for universal health coverage and health security during the COVID-19 pandemic and beyond*. Geneva: World Health Organisation; 2021. <https://www.who.int/publications/i/item/WHO-UHL-PHC-SP-2021.01> [Accessed 1st December 2022].
 42. Phillips DE, Dieleman JL, Lim SS, Shearer J. Determinants of effective vaccine coverage in low and middle-income countries: a systematic review and interpretive synthesis. *BMC Health Services Research*. 2017;17(1): 681. <https://doi.org/10.1186/s12913-017-2626-0>.
 43. Watkins DA, Jamison DT, Mills A, Atun R, Danforth K, Glassman A, et al. *Disease Control Priorities 3: Volume 9 - Improving Health and Reducing Poverty*. Disease Control Priorities: Improving Health and Reducing Poverty. 2017. <https://doi.org/10.1596/978-1-4648-0527-1/pt1.ch3>.
 44. McGovern ME, Canning D. Vaccination and All-Cause Child Mortality From 1985 to 2011: Global Evidence From the Demographic and Health Surveys. *American Journal of Epidemiology*. 2015;182(9): 791–798. <https://doi.org/10.1093/aje/kwv125>.
 45. Chang AY, Riumallo-Herl C, Perales NA, Clark S, Clark A, Constenla D, et al. The Equity Impact Vaccines May Have On Averting Deaths And Medical Impoverishment In Developing Countries. *Health Affairs*. 2018;37(2): 316–324. <https://doi.org/10.1377/hlthaff.2017.0861>.
 46. Sim SY, Watts E, Constenla D, Brenzel L, Patenaud BN. Return on investment from immunization against 10 pathogens in 94 low-and middle-income countries, 2011–30. *Health Affairs*. 2020;39(8): 1343–1353. <https://doi.org/10.1377/hlthaff.2020.00103>.
 47. Close RM, Pearson C, Cohn J. Vaccine-preventable disease and the under-utilization of immunizations in complex humanitarian emergencies. *Vaccine*. 2016;34(39): 4649–4655. <https://doi.org/10.1016/J.VACCINE.2016.08.025>.
 48. Connolly MA, Gayer M, Ryan MJ, Salama P, Spiegel P, Heymann DL. Communicable diseases in complex emergencies: impact and challenges. *The Lancet*. 2004;364(9449): 1974–1983. [https://doi.org/10.1016/S0140-6736\(04\)17481-3](https://doi.org/10.1016/S0140-6736(04)17481-3).
 49. WHO, UNICEF. *Progress and Challenges with achieving Universal Immunization Coverage: 2017 WHO/UNICEF Estimates of National immunization Coverage*. 2018. http://www.who.int/immunization/monitoring_surveillance/who-immuniz.pdf?ua=1
 50. WHO, UNICEF. *Progress and Challenges with Achieving Universal Immunization Coverage, UNICEF and the World Health Organization, July 2020*. 2019. https://www.who.int/immunization/monitoring_surveillance/who-immuniz.pdf

51. Lam E, McCarthy A, Brennan M. Vaccine-preventable diseases in humanitarian emergencies among refugee and internally-displaced populations. *Human Vaccines & Immunotherapeutics*. 2015;11(11): 2627–2636. <https://doi.org/10.1080/21645515.2015.1096457>.
52. Lam E, Diaz M, Maina AGK, Brennan M. Displaced populations due to humanitarian emergencies and its impact on global eradication and elimination of vaccine-preventable diseases. *Conflict and Health*. 2016; <https://doi.org/10.1186/s13031-016-0094-5>.
53. Shearer JC, Walker DG, Risko N, Levine OS. The impact of new vaccine introduction on the coverage of existing vaccines: A cross-national, multivariable analysis. *Vaccine*. 2012;30(52): 7582–7587. <https://doi.org/10.1016/j.vaccine.2012.10.036>.
54. Ammar W, Kdouh O, Hammoud R, Hamadeh R, Harb H, Ammar Z, et al. Health system resilience: Lebanon and the Syrian refugee crisis. *Journal of Global Health*. 2016;6(2): 020704. <https://doi.org/10.7189/jogh.06.020704>.
55. Robertson T, Weiss W, Doocy S. Challenges in Estimating Vaccine Coverage in Refugee and Displaced Populations: Results From Household Surveys in Jordan and Lebanon. *Vaccines*. 2017;5(3): 22. <https://doi.org/10.3390/vaccines5030022>.
56. Navarro-Colorado C, Mahamud A, Burton A, Haskew C, Maina GK, Wagacha JB, et al. Measles outbreak response among adolescent and adult Somali refugees displaced by famine in Kenya and Ethiopia, 2011. *Journal of Infectious Diseases*. 2014;210(12): 1863–1870. <https://doi.org/10.1093/infdis/jiu395>.
57. Polonsky JA, Ronsse A, Ciglenecki I, Rull M, Porten K. High levels of mortality, malnutrition, and measles, among recently-displaced Somali refugees in Dagahaley camp, Dadaab refugee camp complex, Kenya, 2011. *Conflict and Health*. 2013;7(1). <https://doi.org/10.1186/1752-1505-7-1>.
58. van Zandvoort K, Checchi F, Diggle E, Eggo RM, Gadroen K, Mulholland K, et al. Pneumococcal conjugate vaccine use during humanitarian crises. *Vaccine*. 2019;37(45): 6787–6792. <https://doi.org/10.1016/j.vaccine.2019.09.038>.
59. Peprah D, Palmer JJ, Rubin GJ, Abubakar A, Costa A, Martin S, et al. Perceptions of oral cholera vaccine and reasons for full, partial and non-acceptance during a humanitarian crisis in South Sudan. *Vaccine*. 2016;34(33): 3823–3827. <https://doi.org/10.1016/j.vaccine.2016.05.038>.
60. Afzal MH, Jafar AJN. A scoping review of the wider and long-term impacts of attacks on healthcare in conflict zones. *Medicine, Conflict and Survival*. 2019;35(1): 43–64. <https://doi.org/10.1080/13623699.2019.1589687>.
61. Fouad FM, Sparrow A, Tarakji A, Alameddine M, El-Jardali F, Coutts AP, et al. Health workers and the weaponisation of health care in Syria: a preliminary inquiry for The Lancet –American University of Beirut Commission on Syria. *The Lancet*. 2017;390(10111): 2516–2526. [https://doi.org/10.1016/S0140-6736\(17\)30741-9](https://doi.org/10.1016/S0140-6736(17)30741-9).
62. Varghese J, Kutty VR, Paina L, Adam T. Advancing the application of systems thinking in health: understanding the growing complexity governing immunization services in Kerala, India. *Health Research Policy and Systems*. 2014;12(1): 47. <https://doi.org/10.1186/1478-4505-12-47>.
63. Ozawa S, Paina L, Qiu M. Exploring pathways for building trust in vaccination and strengthening health system resilience. *BMC Health Services Research*. 2016;16(S7): 639. <https://doi.org/10.1186/s12913-016-1867-7>.
64. Nnadi C, Etsano A, Uba B, Ohuabunwo C, Melton M, Wa Nganda G, et al. Approaches to Vaccination among Populations in Areas of Conflict. *Journal of Infectious Diseases*. 2017;216: S368–S372. <https://doi.org/10.1093/infdis/jix175>.
65. Tauil M de C, Sato APS, Waldman EA. Factors associated with incomplete or delayed vaccination across countries: A systematic review. *Vaccine*. 2016;34(24): 2635–2643. <https://doi.org/10.1016/J.VACCINE.2016.04.016>.
66. Fawaz M. Planning and the refugee crisis: Informality as a framework of analysis and reflection. *Planning Theory*. 2017;16(1): 99–115. <https://doi.org/10.1177/1473095216647722>.
67. Campbell EH. Urban Refugees in Nairobi: Problems of Protection, Mechanisms of Survival, and Possibilities for Integration. *Journal of Refugee Studies*. 2006;19(3): 396–413. <https://doi.org/10.1093/jrs/fel011>.

68. Guterres A, Spiegel P. The State of the World's Refugees. *JAMA*. 2012;308(7): 673. <https://doi.org/10.1001/2012.jama.10161>.
69. Checchi F, Warsame A, Treacy-Wong V, Polonsky J, Ommeren M van, Prudhon C. Public health information in crisis-affected populations: a review of methods and their use for advocacy and action. *The Lancet*. 2017;390(10109): 2297–2313. [https://doi.org/10.1016/S0140-6736\(17\)30702-X](https://doi.org/10.1016/S0140-6736(17)30702-X).
70. Diggle E, Welsch W, Sullivan R, Alkema G, Warsame A, Wafai M, et al. The role of public health information in assistance to populations living in opposition and contested areas of Syria, 2012–2014. *Conflict and Health*. 2017;11(1): 33. <https://doi.org/10.1186/s13031-017-0134-9>.
71. Diaconu K, Falconer J, Vidal N, O'May F, Azasi E, Elimian K, et al. Understanding fragility: Implications for global health research and practice. *Health Policy and Planning*. 2020;35(2): 235–243. <https://doi.org/10.1093/heapol/czz142>.
72. Martineau T, McPake B, Theobald S, Raven J, Ensor T, Fustukian S, et al. Leaving no one behind: lessons on rebuilding health systems in conflict- and crisis-affected states. *BMJ Global Health*. 2017;2(2): e000327. <https://doi.org/10.1136/bmjgh-2017-000327>.
73. Spiegel PB. The humanitarian system is not just broke, but broken: Recommendations for future humanitarian action. *The Lancet*. 2017;6736(17): 1–8. [https://doi.org/10.1016/S0140-6736\(17\)31278-3](https://doi.org/10.1016/S0140-6736(17)31278-3).
74. Guterres A, Spiegel P. The State of the World's Refugees. *JAMA*. 2012;308(7): 673. <https://doi.org/10.1001/2012.jama.10161>.
75. Leach K, Checchi F. The utilisation of vaccines in humanitarian crises, 2015–2019: A review of practice. *Vaccine*. 2022;40(21): 2970–2978. <https://doi.org/10.1016/j.vaccine.2022.03.034>.
76. WHO. *Global Vaccine Action Plan, 2011-2020*. Geneva: World Health Organisation; 2013. <https://www.who.int/publications/m/item/progress-and-challenges-with-achieving-universal-immunization-coverage> [Accessed 1st December 2022].
77. WHO Strategic Advisory Group of Experts (SAGE) on Immunization. *Immunization Today and in the Next Decade: 2018 Assessment Report for the Global Vaccine Action Plan*. Geneva: World Health Organisation; 2018. <https://apps.who.int/iris/bitstream/handle/10665/276967/WHO-IVB-18.11-eng.pdf> [Accessed 1st December 2022].
78. Gavi. *Fragility, Emergencies, Refugees Policy - version 3.0*. Geneva: Gavi the Vaccine Alliance; 2018. <https://www.gavi.org/programmes-impact/programmatic-policies/fragility-emergencies-and-displaced-populations-policy> [Accessed 1st December 2022].
79. UNICEF. *Core Commitments for Children in Humanitarian Action*. New York: UNICEF; 2010. <https://www.corecommitments.unicef.org/cc-c-to-c> [Accessed 1st December 2022].
80. Blanchet K, Roberts B. *An evidence review of research on health interventions in humanitarian crises - LSHTM*. London: London School of Hygiene and Tropical Medicine; 2015. <http://www.elrha.org/wp-content/uploads/2015/01/Evidence-Review-22.10.15.pdf>
81. Schuh HB, Merritt MW, Igusa T, Lee BY, Peters DH. Examining the structure and behavior of Afghanistan's routine childhood immunization system using system dynamics modeling. *International Journal of Health Governance*. 2017;22(3): 212–227. <https://doi.org/10.1108/IJHG-04-2017-0015>.
82. WHO. *Vaccination in Acute Humanitarian Emergencies: a framework for decision making*. Geneva: World Health Organisation; 2017. <https://apps.who.int/iris/handle/10665/255575> [Accessed 1st December 2022].
83. WHO. *Vaccination in Humanitarian Emergencies: implementation guide*. Geneva: World Health Organisation; 2017. <https://www.who.int/publications/i/item/WHO-IVB-17.13> [Accessed 1st December 2022].
84. WHO SAGE Working Group on vaccination in humanitarian emergencies. *Vaccination in Humanitarian Emergencies: literature review and case studies*. World Health Organisation; 2011. http://www.who.int/immunization/sage/meetings/2012/april/2_SAGE_WGVHE_SG1__Lit_Review_CaseStudies.pdf [Accessed 1st December 2022].
85. Doocy S, Lyles E, Tappis H. *An evidence review of research on health interventions in humanitarian crises: 2021 update*. Baltimore: Johns Hopkins University; 2022.

- <https://www.elrha.org/researchdatabase/the-humanitarian-health-evidence-review-2021-update/> [Accessed 1st December 2022].
86. Teleb N, Hajjeh R. Vaccine preventable diseases and immunization during humanitarian emergencies: challenges and lessons learned from the Eastern Mediterranean Region. *Eastern Mediterranean Health Journal*. 2016;22(11): 775–777. <https://doi.org/10.26719/2016.22.11.775>.
 87. van Olmen J, Marchal B, van Damme W, Kegels G, Hill PS. Health systems frameworks in their political context: framing divergent agendas. *BMC Public Health*. 2012;12(1): 774. <https://doi.org/10.1186/1471-2458-12-774>.
 88. WHO. *Monitoring the building blocks of health systems: a handbook of indicators and their measurement strategies*. Geneva: World Health Organisation; 2010. <https://apps.who.int/iris/handle/10665/258734> [Accessed 30th November 2022].
 89. Savigny D de, Adam T. *Systems Thinking for Health Systems Strengthening*. Geneva: World Health Organisation; 2009. <https://apps.who.int/iris/handle/10665/44204>
 90. WHO. *Global Routine Immunization Strategies and Practices (GRISP). A companion document to the Global Vaccine Action Plan (GVAP)*. World Health Organization. Geneva: World Health Organisation; 2016. <https://apps.who.int/iris/handle/10665/204500> [Accessed 1st December 2022].
 91. Vandelaer J, Bilous J, Nshimirimana D. The Reaching Every District (RED) approach as a way to improve immunization performance. *Bulletin of the World Health Organization*. 2008;86(3): 240–240. <https://doi.org/10.2471/BLT.07.042127>.
 92. Olmen J van, Criel B, Bhojani U, Marchal B, Belle S van, Chenge MF, et al. The Health System Dynamics Framework: The introduction of an analytical model for health system analysis and its application to two case-studies. *Health, Culture and Society*. 2012;2(1): 1–21. <https://doi.org/10.5195/hcs.2012.71>.
 93. Borghi J, Chalabi Z. Square peg in a round hole: re-thinking our approach to evaluating health system strengthening in low-income and middle-income countries. *BMJ Global Health*. 2017;2(3): e000406. <https://doi.org/10.1136/bmjgh-2017-000406>.
 94. El-Sayed AM, Galea S. *Systems science and population health*. New York: Oxford University Press; 2017.
 95. Carey G, Malbon E, Carey N, Joyce A, Crammond B, Carey A. Systems science and systems thinking for public health: a systematic review of the field. *BMJ open*. 2015;5(12): e009002. <https://doi.org/10.1136/bmjopen-2015-009002>.
 96. Rusoja E, Haynie D, Sievers J, Mustafee N, Nelson F, Reynolds M, et al. Thinking about complexity in health: A systematic review of the key systems thinking and complexity ideas in health. *Journal of Evaluation in Clinical Practice*. 2018;24(3): 600–606. <https://doi.org/10.1111/jep.12856>.
 97. de Savigny D, Blanchet K, Adam T. *Applied systems thinking for health systems research: a methodological handbook*. McGraw Hill; 2017.
 98. Blanchet K, Palmer J, Palanchowke R, Boggs D, Jama A, Girois S. Advancing the application of systems thinking in health: analysing the contextual and social network factors influencing the use of sustainability indicators in a health system – a comparative study in Nepal and Somaliland. *Health Research Policy and Systems*. 2014;12(1): 46. <https://doi.org/10.1186/1478-4505-12-46>.
 99. Blanchet K, Girois S, Urseau I, Smerdon C, Drouet Y, Jama A. Physical rehabilitation in post-conflict settings: analysis of public policy and stakeholder networks. *Disability and Rehabilitation*. 2014;36(18): 1494–1501. <https://doi.org/10.3109/09638288.2013.790489>.
 100. Blanchet K, James P. The role of social networks in the governance of health systems: the case of eye care systems in Ghana. *Health Policy and Planning*. 2013;28(2): 143–156. <https://doi.org/10.1093/heapol/czs031>.
 101. Shearer JC. Policy entrepreneurs and structural influence in integrated community case management policymaking in Burkina Faso. *Health Policy and Planning*. 2015;30(suppl 2): ii46–ii53. <https://doi.org/10.1093/heapol/czv044>.

102. Rwashana AS, Williams DW, Neema S. System dynamics approach to immunization healthcare issues in developing countries: A case study of Uganda. *Health Informatics Journal*. 2009;15(2): 95–107. <https://doi.org/10.1177/1460458209102971>.
103. Rwashana AS, Nakubulwa S, Nakakeeto-Kijambu M, Adam T. Advancing the application of systems thinking in health: understanding the dynamics of neonatal mortality in Uganda. *Health Research Policy and Systems*. 2014;12(1): 36. <https://doi.org/10.1186/1478-4505-12-36>.
104. Semwanga AR, Nakubulwa S, Adam T. Applying a system dynamics modelling approach to explore policy options for improving neonatal health in Uganda. *Health Research Policy and Systems*. 2016;14(1): 35. <https://doi.org/10.1186/s12961-016-0101-8>.
105. Lembani M, de Pinho H, Delobelle P, Zarowsky C, Mathole T, Ager A. Understanding key drivers of performance in the provision of maternal health services in eastern cape, South Africa: a systems analysis using group model building. *BMC Health Services Research*. 2018;18(1): 912. <https://doi.org/10.1186/s12913-018-3726-1>.
106. Brailsford S, de Silva D. How many dentists does Sri Lanka need? Modelling to inform policy decisions. *Journal of the Operational Research Society*. 2015;66(9): 1566–1577. <https://doi.org/10.1057/jors.2014.136>.
107. Besiou M, Stapleton O, van Wassenhove LN. System dynamics for humanitarian operations. *Journal of Humanitarian Logistics and Supply Chain Management*. 2011;1(1): 78–103. <https://doi.org/10.1108/20426741111122420>.
108. Gonçalves P. Balancing provision of relief and recovery with capacity building in humanitarian operations. *Operations Management Research*. 2011;4(1–2): 39–50. <https://doi.org/10.1007/s12063-011-0045-7>.
109. Voyer J, Dean M, Pickles C. *Understanding humanitarian supply chain logistics with system dynamics modeling*. System Dynamics Society. Portland; 2015. <https://www.alnap.org/system/files/content/resource/files/main/P1164.pdf> [Accessed 26th October 2019].
110. Ager AK, Lembani M, Mohammed A, Mohammed Ashir G, Abdulwahab A, de Pinho H, et al. Health service resilience in Yobe state, Nigeria in the context of the Boko Haram insurgency: a systems dynamics analysis using group model building. *Conflict and Health*. 2015;9(1): 30. <https://doi.org/10.1186/s13031-015-0056-3>.
111. Jamal Z, Alameddine M, Diaconu K, Lough G, Witter S, Ager A, et al. Health system resilience in the face of crisis: Analysing the challenges, strategies and capacities for UNRWA in Syria. *Health Policy and Planning*. 2020;35(1): 26–35. <https://doi.org/10.1093/heapol/czz129>.
112. Richardson GP. Reflections on the foundations of system dynamics. *System Dynamics Review*. 2011;27(3): 219–243. <https://doi.org/10.1002/sdr.462>.
113. Sterman JD. *Business Dynamics: Systems Thinking and Modeling for a Complex World*. McGraw-Hill Companies Inc; 2000.
114. Cassidy R, Borghi J, Semwanga AR, Binyaruka P, Singh NS, Blanchet K. How to do (or not to do)...using causal loop diagrams for health system research in low and middle-income settings. *Health Policy and Planning*. 2022; 1–9. <https://doi.org/10.1093/heapol/czac064>.
115. Morecroft JDW. *Strategic modelling and business dynamics: a feedback systems approach*. Chichester: Wiley; 2007.
116. Martinez-Moyano IJ, Richardson GP. Best practices in system dynamics modeling. *System Dynamics Review*. 2013;29(2): 102–123. <https://doi.org/10.1002/sdr.1495>.
117. Tomoaia-Cotisel A, Kim H, Allen SD, Blanchet K. Causal loop diagrams: a tool for visualizing emergent system behaviour. In: de Savigny D, Blanchet K, Adam T (eds.) *Applied Systems Thinking for Health Systems Research*. London: McGraw Hill; 2017. p. 97–114.
118. Olaya C. Cows, agency, and the significance of operational thinking. *System Dynamics Review*. 2016;31(4): 183–219. <https://doi.org/10.1002/sdr>.
119. Topp SM. Power and politics: The case for linking resilience to health system governance. *BMJ Global Health*. 2020;5(6). <https://doi.org/10.1136/bmjgh-2020-002891>.

120. Cosens BA. Legitimacy, adaptation, and resilience in ecosystem management. *Ecology and Society*. 2013;18(1). <https://doi.org/10.5751/ES-05093-180103>.
121. Chaffin BC, Garmestani AS, Gunderson LH, Benson MH, Angeler DG, Arnold CA (Tony), et al. Transformative Environmental Governance. *Annual Review of Environment and Resources*. 2016;41(1): 399–423. <https://doi.org/10.1146/annurev-environ-110615-085817>.
122. Lane DC. Rerum cognoscere causas: Part II - Opportunities generated by the agency/structure debate and suggestions for clarifying the social theoretic position of system dynamics. *System Dynamics Review*. 2001;17(4): 293–309. <https://doi.org/10.1002/sdr.221>.
123. Lane DC. Should system dynamics be described as a 'hard' or 'deterministic' systems approach? *Systems Research and Behavioral Science*. 2000;17(1): 3–22. [https://doi.org/10.1002/\(SICI\)1099-1743\(200001/02\)17:1<3::AID-SRES344>3.0.CO;2-7](https://doi.org/10.1002/(SICI)1099-1743(200001/02)17:1<3::AID-SRES344>3.0.CO;2-7).
124. Holland JH. Studying Complex Adaptive Systems. *Journal of Systems Science and Complexity*. 2006;19(1): 1–8. <https://doi.org/10.1007/s11424-006-0001-z>.
125. Barnett MN. Humanitarian Governance. *Annual Review of Political Science*. 2013;16(1): 379–398. <https://doi.org/10.1146/annurev-polisci-012512-083711>.
126. Cliffe L, Luckham R. What happens to the state in conflict?: Political analysis as a tool for planning humanitarian assistance. *Disasters*. 2000;24(4): 291–313. <https://doi.org/10.1111/1467-7717.00150>.
127. Legido-quigley H, Asgari N, Teo YY, Leung GM, Oshitani H, Fukuda K, et al. Are high-performing health systems resilient against the COVID-19 epidemic? *The Lancet*. 2020;395(10227): 848–850. [https://doi.org/10.1016/S0140-6736\(20\)30551-1](https://doi.org/10.1016/S0140-6736(20)30551-1).
128. Haldane V, Morgan GT. From resilient to transilient health systems: the deep transformation of health systems in response to the COVID-19 pandemic. *Health Policy and Planning*. 2021;36(1): 134–135. <https://doi.org/10.1093/heapol/czaa169>.
129. WHO. *Everybody's Business: strengthening health systems to improve health outcomes*. Geneva: World Health Organisation; 2007. <https://apps.who.int/iris/handle/10665/43918> [Accessed 1st December 2022].
130. Frenk J. The Global Health System: Strengthening National Health Systems as the Next Step for Global Progress. *PLoS Medicine*. 2010;7(1): e1000089. <https://doi.org/10.1371/journal.pmed.1000089>.
131. Goldin I, Mariathasan M. *The Butterfly Defect*. Princeton: Princeton University Press; 2014.
132. Linkov I, Bridges T, Creutzig F, Decker J, Fox-Lent C, Kröger W, et al. Changing the resilience paradigm. *Nature Climate Change*. 2014;4(6): 407–409. <https://doi.org/10.1038/nclimate2227>.
133. Zevenbergen C, Gersonius B, Radhakrishnan M. Flood resilience. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*. 2020;378(2168): 20190212. <https://doi.org/10.1098/rsta.2019.0212>.
134. Hosseini S, Barker K, Ramirez-Marquez JE. A review of definitions and measures of system resilience. *Reliability Engineering and System Safety*. 2016;145: 47–61. <https://doi.org/10.1016/j.res.2015.08.006>.
135. Deubelli TM, Mechler R. Perspectives on transformational change in climate risk management and adaptation. *Environmental Research Letters*. 2021;16(5): 3002. <https://doi.org/10.1088/1748-9326/abd42d>.
136. Moser S, Meerow S, Arnott J, Jack-Scott E. The turbulent world of resilience: interpretations and themes for transdisciplinary dialogue. *Climatic Change*. 2019;153(1–2): 21–40. <https://doi.org/10.1007/s10584-018-2358-0>.
137. Blanchet K, Diaconu K, Witter S. Understanding the Resilience of Health Systems. In: Bozorgmehr K, Roberts B, Razum O, Biddle L (eds.) *Health Policy and Systems Responses to Forced Migration*. Cham: Springer International Publishing; 2020. p. 99–117. https://doi.org/10.1007/978-3-030-33812-1_6.
138. Grimm PY, Oliver S, Merten S, Han WW, Wyss K. Enhancing the Understanding of Resilience in Health Systems of Low- and Middle-income Countries: A Qualitative Evidence Synthesis. 2021;(x): 1–13. <https://doi.org/10.34172/ijhpm.2020.261>.

139. Nuzzo JB, Meyer D, Snyder M, Ravi SJ, Lapascu A, Souleles J, et al. What makes health systems resilient against infectious disease outbreaks and natural hazards? Results from a scoping review. *BMC Public Health*. 2019;19(1): 1–9. <https://doi.org/10.1186/s12889-019-7707-z>.
140. Barasa EW, Cloete K, Gilson L. From bouncing back, to nurturing emergence: Reframing the concept of resilience in health systems strengthening. *Health Policy and Planning*. 2017;32: iii91–iii94. <https://doi.org/10.1093/heapol/czx118>.
141. Fraccascia L, Giannoccaro I, Albino V. Resilience of Complex Systems: State of the Art and Directions for Future Research. *Complexity*. 2018;2018: 1–44. <https://doi.org/10.1155/2018/3421529>.
142. Standish RJ, Hobbs RJ, Mayfield MM, Bestelmeyer BT, Suding KN, Battaglia LL, et al. Resilience in ecology: Abstraction, distraction, or where the action is? *Biological Conservation*. 2014;177: 43–51. <https://doi.org/10.1016/j.biocon.2014.06.008>.
143. Ramey VA. Macroeconomic Shocks and Their Propagation. In: *Handbook of Macroeconomics*. 2016. p. 71–162. <https://doi.org/10.1016/bs.hesmac.2016.03.003>.
144. Martin R, Sunley P. On the notion of regional economic resilience: Conceptualization and explanation. *Journal of Economic Geography*. 2015;15(1): 1–42. <https://doi.org/10.1093/jeg/lbu015>.
145. Briguglio L, Cordina G, Farrugia N, Vella S. Economic vulnerability and resilience: Concepts and measurements. *Oxford Development Studies*. 2009;37(3): 229–247. <https://doi.org/10.1080/13600810903089893>.
146. Summers MP, Barker SG. On the Resilience of Systems of Systems. *Annual IEEE International Systems Conference (SysCon)*. 2017;(April): 759–765. https://dSPACE.lib.cranfield.ac.uk/bitstream/handle/1826/12137/Resilience_of_systems_of_systems-2017.pdf?sequence=3&isAllowed=y
147. Uday P, Marais K. Designing resilient systems-of-systems: a survey of metrics, methods and challenges. *Systems Engineering*. 2015;18(5): 491–510. <https://doi.org/10.1002/sys>.
148. Walker BH, Carpenter SR, Rockstrom J, Crépin AS, Peterson GD. Drivers, ‘Slow’ Variables, ‘Fast’ Variables, Shocks, and Resilience. *Ecology and Society*. 2012;17(3): art30. <https://doi.org/10.5751/ES-05063-170330>.
149. del Giudice M, Buck CL, Chaby LE, Gormally BM, Taff CC, Thawley CJ, et al. What Is Stress? A Systems Perspective. *Integrative and Comparative Biology*. 2018;58(6): 1019–1032. <https://doi.org/10.1093/icb/icy114>.
150. Carpenter S, Walker B, Anderies JM, Abel N. From Metaphor to Measurement: Resilience of What to What? *Ecosystems*. 2001;4(8): 765–781. <https://doi.org/10.1007/s10021-001-0045-9>.
151. Stuckler D, Basu S, Suhrcke M, McKee M. The health implications of financial crisis: A review of the evidence. *Ulster Medical Journal*. 2009;78(3): 142–145.
152. Lebel L, Anderies JM, Campbell B, Folke C, Hatfield-Dodds S, Hughes TP, et al. Governance and the capacity to manage resilience in regional social-ecological systems. *Ecology and Society*. 2006;11(1). <https://doi.org/10.5751/ES-01606-110119>.
153. Naimoli JF, Saxena S. Realizing their potential to become learning organizations to foster health system resilience: Opportunities and challenges for health ministries in low-and middle-income countries. *Health Policy and Planning*. 2018;33(10): 1083–1095. <https://doi.org/10.1093/heapol/czy100>.
154. Bowsher G, Bernard R, Sullivan R. A Health Intelligence Framework for Pandemic Response: Lessons from the UK Experience of COVID-19. *Health Security*. 2020;18(6): 435–443. <https://doi.org/10.1089/hs.2020.0108>.
155. Quinlan AE, Berbés-Blázquez M, Haider LJ, Peterson GD. Measuring and assessing resilience: broadening understanding through multiple disciplinary perspectives. *Journal of Applied Ecology*. 2016;53(3): 677–687. <https://doi.org/10.1111/1365-2664.12550>.
156. Folke C, Carpenter SR, Walker B, Scheffer M, Chapin T, Rockström J. Resilience thinking: Integrating resilience, adaptability and transformability. *Ecology and Society*. 2010;15(4). <https://doi.org/10.5751/ES-03610-150420>.

157. Keating A, Campbell K, Mechler R, Magnuszewski P, Mochizuki J, Liu W, et al. Disaster resilience: what it is and how it can engender a meaningful change in development policy. *Development Policy Review*. 2017;35(1): 65–91. <https://doi.org/10.1111/dpr.12201>.
158. Barrett CB, Constan MA. Toward a theory of resilience for international development applications. *Proceedings of the National Academy of Sciences of the United States of America*. 2014;111(40): 14625–14630. <https://doi.org/10.1073/pnas.1320880111>.
159. Lade SJ, Haider LJ, Engström G, Schlüter M. Resilience offers escape from trapped thinking on poverty alleviation. *Science Advances*. 2017;3(5): 1–12. <https://doi.org/10.1126/sciadv.1603043>.
160. Meerow S, Newell JP, Stults M. Defining urban resilience: A review. *Landscape and Urban Planning*. 2016;147: 38–49. <https://doi.org/10.1016/j.landurbplan.2015.11.011>.
161. Gao J, Liu X, Li D, Havlin S. Recent progress on the resilience of complex networks. *Energies*. 2015;8(10): 12187–12210. <https://doi.org/10.3390/en81012187>.
162. Siegenfeld AF, Bar-Yam Y. An Introduction to Complex Systems Science and Its Applications. *Complexity*. 2020;2020. <https://doi.org/10.1155/2020/6105872>.
163. Witter S, Wurie H, Chandiwana P, Namakula J, So S, Alonso-Garbayo A, et al. How do health workers experience and cope with shocks? Learning from four fragile and conflict-affected health systems in Uganda, Sierra Leone, Zimbabwe and Cambodia. *Health Policy and Planning*. 2017; <https://doi.org/10.1093/heapol/czx112>.
164. Fukuma S, Ahmed S, Goto R, Inui TS, Atun R, Fukuhara S. Fukushima after the Great East Japan Earthquake: Lessons for developing responsive and resilient health systems. *Journal of Global Health*. 2017; <https://doi.org/10.7189/jogh.07.010501>.
165. Sochas L, Channon AA, Nam S. Counting indirect crisis-related deaths in the context of a low-resilience health system: The case of maternal and neonatal health during the Ebola epidemic in Sierra Leone. *Health Policy and Planning*. 2017; <https://doi.org/10.1093/heapol/czx108>.
166. van de Pas R, Ashour M, Kapilashrami A, Fustukian S. Interrogating resilience in health systems development. *Health Policy and Planning*. 2017;32(suppl_3): iii88–iii90. <https://doi.org/10.1093/heapol/czx110>.
167. Gunderson LH, Holling CS. *Panarchy: understanding transformations in human and natural systems*. Washington DC: Island press; 2002.
168. Fath BD, Dean CA, Katzmair H. Navigating the adaptive cycle: an approach to managing the resilience of social systems. *Ecology and Society*. 2015;20(2): art24. <https://doi.org/10.5751/ES-07467-200224>.
169. Olsson P, Galaz V, Boonstra WJ. Sustainability transformations: a resilience perspective. *Ecology and Society*. 2014;19(4): art1. <https://doi.org/10.5751/ES-06799-190401>.
170. Chaffin BC, Gunderson LH. Emergence, institutionalization and renewal: Rhythms of adaptive governance in complex social-ecological systems. *Journal of Environmental Management*. 2016;165: 81–87. <https://doi.org/10.1016/j.jenvman.2015.09.003>.
171. Kotsadam A, Østby G. Armed conflict and maternal mortality: A micro-level analysis of sub-Saharan Africa, 1989–2013. *Social Science & Medicine*. 2019;239(September): 112526. <https://doi.org/10.1016/j.socscimed.2019.112526>.
172. Wagner Z, Heft-Neal S, Bhutta ZA, Black RE, Burke M, Bendavid E. Armed conflict and child mortality in Africa: a geospatial analysis. *The Lancet*. 2018;392(10150): 857–865. [https://doi.org/10.1016/S0140-6736\(18\)31437-5](https://doi.org/10.1016/S0140-6736(18)31437-5).
173. Brolin Ribacke KJ, Saulnier DD, Eriksson A, von Schreeb J. Effects of the West Africa Ebola Virus Disease on Health-Care Utilization – A Systematic Review. *Frontiers in Public Health*. 2016;4(OCT): 1–12. <https://doi.org/10.3389/fpubh.2016.00222>.
174. Moss WJ, Ramakrishnan M, Storms D, Siegle AH, Weiss WM, Lejnev I, et al. Child health in complex emergencies. *Bulletin of the World Health Organization*. 2006;84(1): 58–64. <https://doi.org/10.2471/BLT.04.019570>.

175. Mallett LH, Etzel RA. Flooding: what is the impact on pregnancy and child health? *Disasters*. 2018;42(3): 432–458. <https://doi.org/10.1111/disa.12256>.
176. Kates RW, Travis WR, Wilbanks TJ. Transformational adaptation when incremental adaptations to climate change are insufficient. *Proceedings of the National Academy of Sciences of the United States of America*. 2012;109(19): 7156–7161. <https://doi.org/10.1073/pnas.1115521109>.
177. Few R, Morchain D, Spear D, Mensah A, Bendapudi R. Transformation, adaptation and development: relating concepts to practice. *Palgrave Communications*. 2017;3(1). <https://doi.org/10.1057/palcomms.2017.92>.
178. Sundstrom SM, Allen CR. The adaptive cycle: More than a metaphor. *Ecological Complexity*. 2019;39(June): 100767. <https://doi.org/10.1016/j.ecocom.2019.100767>.
179. Scheffer M, Carpenter S, Foley JA, Folke C, Walker B. Catastrophic shifts in ecosystems. *Nature*. 2001;413(6856): 591–596. <https://doi.org/10.1038/35098000>.
180. Li T, Dong Y, Liu Z. A review of social-ecological system resilience: Mechanism, assessment and management. *Science of the Total Environment*. 2020;723(135): 138113. <https://doi.org/10.1016/j.scitotenv.2020.138113>.
181. WHO. *Health Systems for Health Security*. Geneva: World Health Organisation; 2021. <https://www.who.int/publications/i/item/9789240029682>
182. Alameddine M, Fouad FM, Diaconu K, Jamal Z, Lough G, Witter S, et al. Resilience capacities of health systems: Accommodating the needs of Palestinian refugees from Syria. *Social Science & Medicine*. 2019;220: 22–30. <https://doi.org/10.1016/J.SOCSCIMED.2018.10.018>.
183. Ebi KL, Vanos J, Baldwin JW, Bell JE, Hondula DM, Errett NA, et al. Extreme Weather and Climate Change: Population Health and Health System Implications. *Annual Review of Public Health*. 2021;42(1): 1–23. <https://doi.org/10.1146/annurev-publhealth-012420-105026>.
184. Ebi KL, Boyer C, Bowen KJ, Frumkin H, Hess J. Monitoring and evaluation indicators for climate change-related health impacts, risks, adaptation, and resilience. *International Journal of Environmental Research and Public Health*. 2018;15(9): 1–11. <https://doi.org/10.3390/ijerph15091943>.
185. Ebi KL, Berry P, Hayes K, Boyer C, Sellers S, Enright PM, et al. Stress testing the capacity of health systems to manage climate change-related shocks and stresses. *International Journal of Environmental Research and Public Health*. 2018;15(11): 1–16. <https://doi.org/10.3390/ijerph15112370>.
186. Dakos V, Carpenter SR, van Nes EH, Scheffer M. Resilience indicators: prospects and limitations for early warnings of regime shifts. *Philosophical Transactions of the Royal Society B: Biological Sciences*. 2015;370(1659): 20130263. <https://doi.org/10.1098/rstb.2013.0263>.
187. Witter S, Palmer N, Balabanova D, Mounier-Jack S, Martineau T, Klicpera A, et al. Health system strengthening—Reflections on its meaning, assessment, and our state of knowledge. *The International Journal of Health Planning and Management*. 2019;34(4): hpm.2882. <https://doi.org/10.1002/hpm.2882>.
188. Schlüter M, Müller B, Frank K. The potential of models and modeling for social-ecological systems research: the reference frame ModSES. *Ecology and Society*. 2019;24(1): art31. <https://doi.org/10.5751/ES-10716-240131>.
189. lo Sardo DR, Thurner S, Sorger J, Duftschmid G, Endel G, Klimek P. Quantification of the resilience of primary care networks by stress testing the health care system. *Proceedings of the National Academy of Sciences of the United States of America*. 2019;116(48): 23930–23935. <https://doi.org/10.1073/pnas.1904826116>.
190. Herrera de Leon HJ, Kopainsky B. Do you bend or break? System dynamics in resilience planning for food security. *System Dynamics Review*. 2019;35(4): 287–309. <https://doi.org/10.1002/sdr.1643>.
191. Herrera H, Kopainsky B. Using system dynamics to support a participatory assessment of resilience. *Environment Systems and Decisions*. 2020;(0123456789). <https://doi.org/10.1007/s10669-020-09760-5>.
192. Rahmandad H, Sterman J. Heterogeneity and network structure in the dynamics of diffusion: Comparing agent-based and differential equation models. *Management Science*. 2008;54(5): 998–1014. <https://doi.org/10.1287/mnsc.1070.0787>.

193. Stroeve SH, Everdij MHC. Agent-based modelling and mental simulation for resilience engineering in air transport. *Safety Science*. 2017;93: 29–49. <https://doi.org/10.1016/j.ssci.2016.11.003>.
194. Egli L, Weise H, Radchuk V, Seppelt R, Grimm V. Exploring resilience with agent-based models: State of the art, knowledge gaps and recommendations for coping with multidimensionality. *Ecological Complexity*. 2019;40(August 2018): 100718. <https://doi.org/10.1016/j.ecocom.2018.06.008>.
195. Gotts NM, van Voorn GAK, Polhill JG, Jong E de, Edmonds B, Hofstede GJ, et al. Agent-based modelling of socio-ecological systems: Models, projects and ontologies. *Ecological Complexity*. 2019;40. <https://doi.org/10.1016/j.ecocom.2018.07.007>.
196. Zhuo L, Han D. Agent-based modelling and flood risk management: A compendious literature review. *Journal of Hydrology*. 2020;591(October): 125600. <https://doi.org/10.1016/j.jhydrol.2020.125600>.
197. Hassan EM, Mahmoud H. Healthcare and education networks interaction as an indicator of social services stability following natural disasters. *Scientific Reports*. 2021;11(1): 1–15. <https://doi.org/10.1038/s41598-021-81130-w>.
198. Crisis Group. *Managing Lebanon's Compounding Crises*. Brussels: Crisis Group; 2021. <https://www.crisisgroup.org/middle-east-north-africa/east-mediterranean-mena/lebanon/228-managing-lebanons-compounding-crises> [Accessed 29th November 2022].
199. Maktabi R. The Lebanese census of 1932 revisited. Who are the Lebanese? *British Journal of Middle Eastern Studies*. 1999;26(2): 219–241. <https://doi.org/10.1080/13530199908705684>.
200. World Bank. *World Bank Indicator Portal*. <https://data.worldbank.org/indicator> [Accessed 29th November 2022].
201. United Nations Department of Economic and Social Affairs. Lebanon. In: *World Population Prospects 2019*. 2020.
202. Institute for Health Metrics and Evaluation. *VizHub - GBD Compare*. <https://vizhub.healthdata.org/gbd-compare/> [Accessed 30th November 2022].
203. UNHCR, UNICEF, WFP, Interagency Coordination - Lebanon. *Vulnerability Assessment of Syrian Refugees (VASyR) in Lebanon, 2018*. Beirut: IACG Lebanon; 2018. <https://data2.unhcr.org/en/documents/download/67380>
204. UNHCR, UNICEF, WFP, Interagency Coordination - Lebanon. *Vulnerability Assessment of Syrian Refugees (VASyR) in Lebanon, 2019*. Beirut: IACG Lebanon; 2019. <https://www.unhcr.org/lb/wp-content/uploads/sites/16/2019/12/VASyR-2019.pdf> [Accessed 1st December 2022].
205. UNHCR, UNICEF, WFP, Interagency Coordination - Lebanon. *Vulnerability Assessment of Syrian Refugees (VASyR) in Lebanon, 2020*. Beirut: IACG Lebanon; 2020. <https://reliefweb.int/report/lebanon/vasyr-2020-vulnerability-assessment-syrian-refugees-lebanon> [Accessed 1st December 2022].
206. R4HC-MENA. *How politics made a nation sick: the political economy of health in Lebanon*. London; 2022. <https://r4hc-mena.org/2022/01/11/lebanon-on-life-support-how-politics-made-a-nation-sick/>
207. UNHCR. *Operational Data Portal: Syria Regional Refugee Response*. <https://data.unhcr.org/en/situations/syria/location/71> [Accessed 29th November 2022].
208. UNRWA. *Where we work: Lebanon*. <https://www.unrwa.org/where-we-work/lebanon> [Accessed 30th November 2022].
209. UNHCR. *Global Trends: force displacement in 2018*. 2019 [Accessed 1st December 2022]. <https://www.unhcr.org/uk/statistics/unhcrstats/5d08d7ee7/unhcr-global-trends-2018.html> [Accessed 1st December 2022].
210. Fakhoury T. Governance Strategies and Refugee Response: Lebanon in the Face of Syrian Displacement. *International Journal of Middle East Studies*. 2017;49(4): 681–700. <https://doi.org/10.1017/S0020743817000654>.
211. Janmyr M. *The Legal Status of Syrian Refugees in Lebanon*. Isaam Fares Institute for Public Policy and International Affairs. Beirut: Issam Fares Institute; 2016. www.syrianrefugees.eu

212. Janmyr M. Precarity in Exile: the legal status of Syrian refugees in Lebanon. *Refugee Survey Quarterly*. 2016;35(November): 58–78. <https://doi.org/10.1093/rsq/hdw016>.
213. Janmyr M. UNHCR and the Syrian refugee response: Negotiating status and registration in Lebanon. *International Journal of Human Rights*. 2018;22(3): 393–419. <https://doi.org/10.1080/13642987.2017.1371140>.
214. UNHCR, UNICEF, WFP, Interagency Coordination - Lebanon. *Vulnerability Assessment for Syrian Refugees (VASyR) 2021*. Beirut: IACG Lebanon; 2021. <https://reliefweb.int/report/lebanon/vasyr-2021-vulnerability-assessment-syrian-refugees-lebanon> [Accessed 1st December 2022].
215. World Bank. *Lebanon Economic Monitor, Fall 2021: the Great Denial*. Washington DC: World Bank; 2021. <https://www.worldbank.org/en/country/lebanon/publication/lebanon-economic-monitor-fall-2021-the-great-denial> [Accessed 1st December 2022].
216. Hamieh CS, mac Ginty R. A very political reconstruction: governance and reconstruction in Lebanon after the 2006 war. *Disasters*. 2010;34(SI): S103–S123. <https://doi.org/10.1111/j.1467-7717.2009.01101.x>.
217. Assouad L. *Rethinking the Lebanese Economic Miracle: The Extreme Concentration of Income and Wealth in Lebanon 2005–2014*. Paris School of Economics Working Papers. Report number: 2017/13, 201AD. <https://halshs.archives-ouvertes.fr/halshs-02160275/>
218. Diwan I. *Lebanon's Perfect Storm*. Project Syndicate. <https://www.project-syndicate.org/commentary/lebanon-political-economic-crises-protests-by-ishac-diwan-2020-01?barrier=accesspaylog> [Accessed 26th November 2022].
219. UNESCWA. *Multidimensional poverty in Lebanon (2019-2021): painful reality and uncertain prospects*. Policy Brief. 2021 [Accessed 1st December 2022]. https://www.unescwa.org/sites/default/files/news/docs/21-00634-_multidimensional_poverty_in_lebanon_policy_brief_-_en.pdf [Accessed 1st December 2022].
220. CAS/ILO. *Lebanon Follow-up Labour Force Survey – January 2022: Factsheet*. 2022. https://www.ilo.org/beirut/publications/WCMS_844837/lang-en/index.htm
221. WHO. *Lebanon: WHO Coronavirus Disease (COVID-19) Dashboard With Vaccination Data*. <https://covid19.who.int/region/emro/country/lb> [Accessed 30th November 2022].
222. Mansour Z, Arab J, Said R, Rady A, Hamadeh R, Gerbaka B, et al. Impact of COVID-19 pandemic on the utilization of routine immunization services in Lebanon. *PLoS ONE*. 2021;16(2 February): 1–11. <https://doi.org/10.1371/journal.pone.0246951>.
223. Jagarnathsingh A, Blakah M, Peltre C, Saleh R, Sebas M. *Access to Healthcare for Syrian Refugees*. 2016. <https://civilsociety-centre.org/sites/default/files/resources/accesshealthcaresyrianrefugees-ls2016.pdf>
224. Kronfol NM. Rebuilding of the Lebanese health care system: Health sector reforms. *Eastern Mediterranean Health Journal*. 2006;12(3–4): 459–473.
225. Kronfol NM, Bashshur R. Lebanon's health care policy: a case study in the evolution of a health system under stress. *Journal of public health policy*. 1989;10(3): 377–396. <http://www.ncbi.nlm.nih.gov/pubmed/2681264>
226. Ammar W. *Health system and reform in Lebanon*. 2003 [Accessed 1st December 2022]. <https://www.moph.gov.lb/en/Pages/131/3932/health-system-and-reform-in-lebanon#/en/view/3910/health-system-and-reform-in-lebanon-2003> [Accessed 1st December 2022].
227. Sen K, Mehio-Sibai A. Transnational Capital and Confessional Politics: The Paradox of the Health Care System in Lebanon. *International Journal of Health Services*. 2004;34(3): 527–551. <https://doi.org/10.2190/6X2V-GE4T-9BQF-WYXB>.
228. van Lerberghe W. Reform follows failure: I. Unregulated private care in Lebanon. *Health Policy and Planning*. 1997;12(4): 296–311. <https://doi.org/10.1093/heapol/12.4.296>.
229. van Lerberghe W. Reform follows failure: II. Pressure for change in the Lebanese health sector. *Health Policy and Planning*. 1997;12(4): 312–319. <https://doi.org/10.1093/heapol/12.4.312>.

230. Yip W, Hafez R. *Reforms for improving the efficiency of health systems: lessons from 10 country cases*. Geneva; 2015. https://www.afro.who.int/sites/default/files/2017-06/WHO_HIS_HGF_SR_15.1_eng.pdf [Accessed 27th September 2021].
231. Blanchet K, Fouad FM, Pherali T. Syrian refugees in Lebanon: the search for universal health coverage. *Conflict and Health*. 2016;10(1): 12.
232. Government of Lebanon. *Lebanon Crisis Response Plan 2017-2020*. Beirut: IACG Lebanon; 2018. <http://www.unhcr.org/lb/wp-content/uploads/sites/16/2018/04/LCRP-EN-2018.pdf%0Adata.unhcr.org/syrianrefugees/download.php?id=7723%0Ahttps://data2.unhcr.org/en/documents/download/64559>
233. Boustani M, Carpi E, Gebara H, Mourad Y. *Responding to the Syrian crisis in Lebanon: collaboration between aid agencies and local governance structures*. London: IIED; 2016. <https://www.iied.org/10799iied> [Accessed 1st December 2022].
234. Sayara International. *Evaluation of Immunisation Programme (EPI) in Lebanon, 2013-17*. Beirut: Sayara International; 2018.
235. Honein-AbouHaidar G, Noubani A, el Arnaout N, Ismail S, Nimer H, Menassa M, et al. Informal healthcare provision in Lebanon: an adaptive mechanism among displaced Syrian health professionals in a protracted crisis. *Conflict and Health*. 2019;13(1): 40. <https://doi.org/10.1186/s13031-019-0224-y>.
236. Ismail SA, Coutts AP, Rayes D, Roborgh S, Abbara A, Orcutt M, et al. *Refugees, healthcare and crises: informal Syrian health workers in Lebanon*. London: IIED; 2018. <https://www.iied.org/10856iied> [Accessed 1st December 2022].
237. Mansour Z, Said R, Brandt L, Khachan J, Rady A, Fahmy K, et al. Factors affecting age-appropriate timeliness of vaccination coverage among children in Lebanon. *Gates Open Research*. 2018;2. <https://doi.org/10.12688/gatesopenres.12898.1>.
238. Mansour Z, Hamadeh R, Rady A, Danovaro-Holliday MC, Fahmy K, Said R, et al. Vaccination coverage in Lebanon following the Syrian crisis: results from the district-based immunization coverage evaluation survey 2016. *BMC Public Health*. 2019;19(1): 58. <https://doi.org/10.1186/s12889-019-6418-9>.
239. Lebanese Ministry of Public Health, WHO. *Expanded Programme on Immunization: district-based immunization coverage cluster survey*. 2016 [Accessed 1st December 2022]. <https://reliefweb.int/report/lebanon/expanded-programme-immunization-district-based-immunization-coverage-cluster-survey> [Accessed 1st December 2022].
240. Kmeid M, Azouri H, Aaraj R, Bechara E, Antonios D. Vaccine coverage for Lebanese citizens and Syrian refugees in Lebanon. *International Health*. 2019; <https://doi.org/10.1093/inthealth/ihz023>.
241. Mbaeyi C, Ryan MJ, Smith P, Mahamud A, Farag N, Haithami S, et al. Response to a Large Polio Outbreak in a Setting of Conflict — Middle East. *Morbidity and Mortality Weekly Report*. 2017;3(8): 2013–2015.
242. Mbaeyi C, Wadood ZM, Moran T, Ather F, Stehling-Ariza T, Nikulin J, et al. Strategic Response to an Outbreak of Circulating Vaccine-Derived Poliovirus Type 2 — Syria, 2017–2018. *MMWR. Morbidity and Mortality Weekly Report*. 2018;67(24): 690–694. <https://doi.org/10.15585/mmwr.mm6724a5>.
243. Helou M, van Berlaer G, Yammine K. Factors influencing the occurrence of infectious disease outbreaks in Lebanon since the Syrian crisis. *Pathogens and Global Health*. 2021;00(00): 1–9. <https://doi.org/10.1080/20477724.2021.1957192>.
244. World Health Organization (WHO). *WHO Immunization Data portal*. <https://immunizationdata.who.int/> [Accessed 30th November 2022].
245. Topp SM, Schaaf M, Sriram V, Scott K, Dalglish SL, Nelson EM, et al. Power analysis in health policy and systems research: A guide to research conceptualisation. *BMJ Global Health*. 2021;6(11). <https://doi.org/10.1136/bmjgh-2021-007268>.
246. Bryman A. *Social Research Methods*.. 4th Edition. Oxford: Oxford University Press; 2018.
247. Sphere Project. *The Sphere Handbook: Humanitarian Charter and Minimum Standards in Humanitarian Response*. SPHERE; 201AD. https://spherestandards.org/wp-content/uploads/2018/06/Sphere_Handbook_2011_English.pdf [Accessed 1st December 2022].

248. Meadows D. *Thinking in Systems: a primer*. Chelsea Green; 2008.
249. Sterman JD. Learning from evidence in a complex world. *American Journal of Public Health*. 2006;96(3): 505–514. <https://doi.org/10.2105/AJPH.2005.066043>.
250. Ager AK, Lembani M, Mohammed A, Mohammed Ashir G, Abdulwahab A, de Pinho H, et al. Health service resilience in Yobe state, Nigeria in the context of the Boko Haram insurgency: a systems dynamics analysis using group model building. *Conflict and Health*. 2015;9(1): 30. <https://doi.org/10.1186/s13031-015-0056-3>.
251. Noubani A, Diaconu K, Ghandour L, el Koussa M, Loffreda G, Saleh S. A community-based system dynamics approach for understanding factors affecting mental Health and Health seeking behaviors in Beirut and Beqaa regions of Lebanon. *Globalization and Health*. 2020;16(1): 1–13. <https://doi.org/10.1186/s12992-020-00556-5>.
252. Kim H, Andersen DF. Building confidence in causal maps generated from purposive text data: mapping transcripts of the Federal Reserve. *System Dynamics Review*. 2012;28(4): 311–328. <https://doi.org/10.1002/sdr>.
253. Tomoaia-Cotisel A, Allen SD, Kim H, Andersen D, Chalabi Z. Rigorously interpreted quotation analysis for evaluating causal loop diagrams in late-stage conceptualization. *System Dynamics Review*. 2022;(January): 1–41. <https://doi.org/10.1002/sdr.1701>.
254. Ventana Systems Inc. *Vensim*. <https://vensim.com/> [Accessed 30th November 2022].
255. Yearworth M, White L. The uses of qualitative data in multimethodology: Developing causal loop diagrams during the coding process. *European Journal of Operational Research*. 2013;231(1): 151–161. <https://doi.org/10.1016/J.EJOR.2013.05.002>.
256. WHO. *Health Systems Governance*. https://www.who.int/health-topics/health-systems-governance#tab=tab_1 [Accessed 29th November 2022].
257. Ritchie J, Spencer L. Qualitative data analysis for applied policy research. In: Huberman AM, Miles MB (eds.) *The Qualitative Researcher's Companion*. Thousand Oaks, CA: SAGE Publications, Inc.; 2002. p. 305–329. <https://doi.org/10.4135/9781412986274>.
258. Gale NK, Heath G, Cameron E, Rashid S, Redwood S. Using the framework method for the analysis of qualitative data in multi-disciplinary health research. *BMC medical research methodology*. 2013;13(1): 117.
259. Pawson R, Walshe K, Greenhalgh T. *Realist synthesis : an introduction*. Manchester: ESRC Research Methods Programme; 2004. https://www.betterevaluation.org/en/resources/guide/realist_synthesis_an_introduction [Accessed 1st December 2022].
260. Wong G, Westhorp G, Manzano A, Greenhalgh J, Jagosh J, Greenhalgh T. RAMESES II reporting standards for realist evaluations. *BMC Medicine*. 2016;14(1): 1–18. <https://doi.org/10.1186/s12916-016-0643-1>.
261. Spangaro J, Adogu C, Zwi AB, Ranmuthugala G, Davies GP. Mechanisms underpinning interventions to reduce sexual violence in armed conflict: A realist-informed systematic review. *Conflict and Health*. 2015;9(1). <https://doi.org/10.1186/s13031-015-0047-4>.
262. O'Campo P, Kirst M, Tsamis C, Chambers C, Ahmad F. Implementing successful intimate partner violence screening programs in health care settings: Evidence generated from a realist-informed systematic review. *Social Science and Medicine*. 2011;72(6): 855–866. <https://doi.org/10.1016/j.socscimed.2010.12.019>.
263. Dryden-Palmer KD, Parshuram CS, Berta WB. Context, complexity and process in the implementation of evidence-based innovation: A realist informed review. *BMC Health Services Research*. 2020;20(1): 1–15. <https://doi.org/10.1186/s12913-020-4935-y>.
264. mac Ginty R, Brett R, Vogel B. *The Companion to Peace and Conflict Fieldwork*. Springer; 2021.
265. Sukarieh M, Tannock S. Subcontracting Academia: Alienation, Exploitation and Disillusionment in the UK Overseas Syrian Refugee Research Industry. *Antipode*. 2019;51(2): 664–680. <https://doi.org/10.1111/anti.12502>.

266. Sukarieh M, Tannock S. On the Problem of Over-researched Communities: The Case of the Shatila Palestinian Refugee Camp in Lebanon. *Sociology*. 2013;47(3): 494–508. <https://doi.org/10.1177/0038038512448567>.
267. Thomas S, Keegan C, Barry S, Layte R, Jowett M, Normand C. A framework for assessing health system resilience in an economic crisis: Ireland as a test case. *BMC Health Services Research*. 2013;13(1): 450. <https://doi.org/10.1186/1472-6963-13-450>.
268. Ling EJ, Larson E, MacAuley RJ, Kodl Y, Vandebogert B, Baawo S, et al. Beyond the crisis: Did the Ebola epidemic improve resilience of Liberia's health system? *Health Policy and Planning*. 2017;32: iii40–iii47. <https://doi.org/10.1093/heapol/czx109>.
269. Mayhew SH, Kyamusugulwa PM, Kihangi Bindu K, Richards P, Kiyungu C, Balabanova D. Responding to the 2018–2020 Ebola Virus Outbreak in the Democratic Republic of the Congo: Rethinking Humanitarian Approaches. *Risk Management and Healthcare Policy*. 2021;Volume 14: 1731–1747. <https://doi.org/10.2147/rmhp.s219295>.
270. Saulnier DD, Hean H, Thol D, Ir P, Hanson C, Schreeb J von, et al. Staying afloat : community perspectives on health system resilience in the management of pregnancy and childbirth care during floods in Cambodia. 2020; 1–12. <https://doi.org/10.1136/bmjgh-2019-002272>.
271. Pescaroli G, Alexander D. Understanding Compound, Interconnected, Interacting, and Cascading Risks: A Holistic Framework. *Risk Analysis*. 2018;38(11): 2245–2257. <https://doi.org/10.1111/risa.13128>.
272. Pescaroli G, Nones M, Galbusera L, Alexander D. Understanding and mitigating cascading crises in the global interconnected system. *International Journal of Disaster Risk Reduction*. 2018;30: 159–163. <https://doi.org/10.1016/j.ijdr.2018.07.004>.
273. Sillmann J, Christensen I, Hochrainer-Stigler S, Huang-Lachmann JT, Juhola S, Kornhuber K, et al. *IS-UNDRR-RISK KAN Briefing note on systemic risk*. 2022. <https://www.undrr.org/publication/briefing-note-systemic-risk>
274. Chang AY, Ogbuoji O, Atun R, Verguet S. Dynamic modeling approaches to characterize the functioning of health systems: A systematic review of the literature. *Social Science & Medicine*. 2017; <https://doi.org/10.1016/j.socscimed.2017.09.005>.
275. Tilloy A, Malamud BD, Winter H, Joly-Laugel A. A review of quantification methodologies for multi-hazard interrelationships. *Earth-Science Reviews*. 2019;196(June): 102881. <https://doi.org/10.1016/j.earscirev.2019.102881>.
276. Gill JC, Malamud BD. Reviewing and visualizing the interactions of natural hazards. *Reviews of Geophysics*. 2014;52(4): 680–722. <https://doi.org/10.1002/2013RG000445>.
277. de Angeli S, Malamud BD, Rossi L, Taylor FE, Trasforini E, Rudari R. A multi-hazard framework for spatial-temporal impact analysis. *International Journal of Disaster Risk Reduction*. 2022;73(February): 102829. <https://doi.org/10.1016/j.ijdr.2022.102829>.
278. Zscheischler J, Westra S, van den Hurk BJJM, Seneviratne SI, Ward PJ, Pitman A, et al. Future climate risk from compound events. *Nature Climate Change*. 2018;8(6): 469–477. <https://doi.org/10.1038/s41558-018-0156-3>.
279. Gill JC, Malamud BD. Hazard interactions and interaction networks (cascades) within multi-hazard methodologies. *Earth System Dynamics*. 2016;7(3): 659–679. <https://doi.org/10.5194/esd-7-659-2016>.
280. Hochrainer-Stigler S, Colon C, Boza G, Poledna S, Rovenskaya E, Dieckmann U. Enhancing resilience of systems to individual and systemic risk: Steps toward an integrative framework. *International Journal of Disaster Risk Reduction*. 2020;51(January). <https://doi.org/10.1016/j.ijdr.2020.101868>.
281. Hamadeh RS, Kdouh O, Hammoud R, Leresche E, Leaning J. Working short and working long: can primary healthcare be protected as a public good in Lebanon today? *Conflict and Health*. 2021;15(1): 1–9. <https://doi.org/10.1186/s13031-021-00359-4>.
282. Tomoaia-Cotisel A. *The Journey toward the Patient-Centered Medical Home: A Grounded, Dynamic Theory of Primary Care Transformation*. LSHTM; 2018. <https://doi.org/10.22201/fq.18708404e.2004.3.66178>.

283. de Ruiter MC, Couasnon A, Homberg MJC, Daniell JE, Gill JC, Ward PJ. Why We Can No Longer Ignore Consecutive Disasters. *Earth's Future*. 2020;8(3). <https://doi.org/10.1029/2019EF001425>.
284. Blanchet K, Roberts B, Sistenich V, Ramesh A, Frison S, Warren E, et al. *An evidence review of research on health interventions in humanitarian crises*. London: London School of Hygiene and Tropical Medicine; 2015. <https://www.elrha.org/wp-content/uploads/2015/01/Evidence-Review-22.10.15.pdf> [Accessed 1st December 2022].
285. Kim RE. Is Global Governance Fragmented, Polycentric, or Complex? The State of the Art of the Network Approach. *International Studies Review*. 2020;22(4): 903–931. <https://doi.org/10.1093/isr/viz052>.
286. Abimbola S, Topp SM. Adaptation with robustness: the case for clarity on the use of 'resilience' in health systems and global health. *BMJ Global Health*. 2018;3(1): e000758. <https://doi.org/10.1136/bmjgh-2018-000758>.
287. Hilhorst D, Desportes I, de Milliano CWJ. Humanitarian governance and resilience building: Ethiopia in comparative perspective. *Disasters*. 2019;43(S2): S109–S131. <https://doi.org/10.1111/disa.12332>.
288. Vigh H. Crisis and Chronicity: Anthropological Perspectives on Continuous Conflict and Decline. *Ethnos*. 2008;73(1): 5–24. <https://doi.org/10.1080/00141840801927509>.
289. Alliance for Health Policy and Systems Research. *Primary Health Care Systems (PRIMASYS): Lebanon case study*. World Health Organization. Geneva: World Health Organisation; 2017. <https://apps.who.int/iris/handle/10665/341171?locale-attribute=en> [Accessed 1st December 2022].
290. Lebanon National HWG. *National Health Working Group Meeting Minute - 27th March 2015*. 2015.
291. Lebanon National HWG. *National Health Working Group Meeting Minute - 27th June 2014*. 2014.
292. Lebanon MoPH. *The MOH Strategic Plan, 2007-2012*. 2007 [Accessed 1st December 2022]. [https://www.moph.gov.lb/en/Pages/0/9909/moph-s-tragic-plan-2007-2012-](https://www.moph.gov.lb/en/Pages/0/9909/moph-s-trategic-plan-2007-2012-) [Accessed 1st December 2022].
293. UNDP Global Risk Identification Program. *Disaster Risk Assessment in Lebanon: a comprehensive country situation analysis*. 2010. <http://www.gripweb.org>
294. UNHCR Lebanon. *Inter-Agency Contingency Plan for Syrian Refugees*. 2013.
295. UNHCR Lebanon. *Inter-Agency Contingency Plan for Syrian Refugees*. 2014.
296. Lebanon National HWG. *National Health Working Group Meeting Minute - 25th April 2014*. 2014.
297. Lebanon National HWG. *National Health Working Group Meeting Minute - 28th March 2014*. 2014.
298. Lebanon National HWG. *National Health Working Group Meeting Minute - 28th January 2022*. 2022.
299. Lebanon National HWG. *National Health Working Group Meeting Minute - 31st May 2018*. 2018.
300. Lebanon National HWG. *National Health Working Group Meeting Minute - 28th May 2021*. 2021.
301. Lebanese Ministry of Public Health. *MoPH PHC Network Annual Report [in Arabic] - 2020*. 2020.
302. Lebanese Ministry of Public Health. *MoPH PHC Network Annual Report [in Arabic] - 2010*. 2010.
303. Held D, Kickbusch I, McNally K, Piselli D, Told M. Gridlock, Innovation and Resilience in Global Health Governance. *Global Policy*. 2019;10(2): 161–177. <https://doi.org/10.1111/1758-5899.12654>.
304. Mufti K. Official response to the Syrian refugee crisis in Lebanon, the disastrous policy of no-policy. *Civil Society Knowledge Centre*. 2014;1(1). <https://doi.org/10.28943/cskc.002.20001>.
305. Brassett J, Croft S, Vaughan-williams N. Introduction : An Agenda for Resilience Research in Politics and International Relations. 2013;33(4): 221–228. <https://doi.org/10.1111/1467-9256.12032>.
306. Rodrigues CMC, Plotkin SA. Impact of Vaccines; Health, Economic and Social Perspectives. *Frontiers in Microbiology*. 2020;11(July). <https://doi.org/10.3389/fmicb.2020.01526>.
307. Ozawa S, Clark S, Portnoy A, Grewal S, Stack ML, Sinha A, et al. Estimated economic impact of vaccinations in 73 low- and middleincome countries, 2001–2020. *Bulletin of the World Health Organization*. 2017;95(9): 629–638. <https://doi.org/10.2471/BLT.16.178475>.

308. Causey K, Fullman N, Sorensen RJD, Galles NC, Zheng P, Aravkin A, et al. Estimating global and regional disruptions to routine childhood vaccine coverage during the COVID-19 pandemic in 2020: a modelling study. *The Lancet*. 2021;398(10299): 522–534. [https://doi.org/10.1016/S0140-6736\(21\)01337-4](https://doi.org/10.1016/S0140-6736(21)01337-4).
309. Blanchet K, Ramesh A, Frison S, Warren E, Hossain M, Smith J, et al. Evidence on public health interventions in humanitarian crises. *The Lancet*. 2017;390(10109): 2287–2296. [https://doi.org/10.1016/S0140-6736\(16\)30768-1](https://doi.org/10.1016/S0140-6736(16)30768-1).
310. Development Initiatives. *Global Humanitarian Assistance Report 2021*. Bristol; 2021. <https://devinit.org/resources/global-humanitarian-assistance-report-2021/> [Accessed 1st December 2022].
311. Ouzzani M, Hammady H, Fedorowicz Z, Elmagarmid A. Rayyan---a web and mobile app for systematic reviews. *Systematic Reviews*. 2016;5(1): 210. <https://doi.org/10.1186/s13643-016-0384-4>.
312. Jagosh J. Realist Synthesis for Public Health: Building an Ontologically Deep Understanding of How Programs Work, for Whom, and in Which Contexts. *Annual Review of Public Health*. 2019;40: 361–372. <https://doi.org/10.1146/annurev-publhealth-031816-044451>.
313. Hong QN, Pluye P, Fàbregues S, Bartlett G, Boardman F, Cargo M, et al. *Mixed Methods Appraisal Tool (MMAT), Version 2018. User guide*. 2018. http://mixedmethodsappraisaltoolpublic.pbworks.com/w/file/attach/127916259/MMAT_2018_criteria-manual_2018-08-01_ENG.pdf
314. Amani A, Fouda AAB, Nangmo AJ, Bama SN, Tatang CA, Mbang MA, et al. Reactive mass vaccination campaign against Cholera in the COVID-19 context in Cameroon: Challenges, best practices and lessons learned. *Pan African Medical Journal*. 2021;38. <https://doi.org/10.11604/pamj.2021.38.392.27754>.
315. Amani A, Bitá A, Nkwele IM, Dairou IA, Nangmo A, Ndongo MN, et al. Preventive mass vaccination campaign against meningococcal meningitis in refugee camps of cameroon during the covid-19 pandemic: Vaccination coverage, challenges, best practices and lessons learned. *International Journal of Tropical Medicine*. 2021;16(3): 41–46. <https://www.embase.com/search/results?subaction=viewrecord&id=L2007881086&from=export%0Ahttp://dx.doi.org/10.36478/ijtm.2021.41.46>
316. Jean Baptiste AE, Wagai J, Luce R, Masresha B, Klinkenberg D, Veldhuijzen I, et al. Measles outbreak in complex emergency: estimating vaccine effectiveness and evaluation of the vaccination campaign in Borno State, Nigeria, 2019. *BMC Public Health*. 2021;21(1): 1–10. <https://doi.org/10.1186/s12889-021-10436-1>.
317. Bwire G, Roskosky M, Ballard A, Brooks WA, Okello A, Rafael F, et al. *Use of surveys to evaluate an integrated oral cholera vaccine campaign in response to a cholera outbreak in Hoima district, Uganda*. *BMJ Open*. 2020. <https://doi.org/10.1136/bmjopen-2020-038464>.
318. Dadgar N, Ansari A, Naleo T, Brennan M, Salama P, Sadozai N, et al. Implementation of a mass measles campaign in Central Afghanistan, December 2001 to May 2002. *Journal of Infectious Diseases*. 2003;187(SUPPL. 1). <https://doi.org/10.1086/368335>.
319. Elsayed E, Mousa N, Dabbagh A, El-Bushra H, Mahoney F, Haithami S. Emergency Measles Control Activities --- Darfur, Sudan, 2004. *MMWR - Morbidity & Mortality Weekly Report*. 2004;53(38): 897–899. <https://www.cdc.gov/mmwr/preview/mmwrhtml/mm5338a3.htm>
320. Khan AI, Islam MT, Siddique SA, Ahmed S, Sheikh N, Siddik AU, et al. Post-vaccination campaign coverage evaluation of oral cholera vaccine, oral polio vaccine and measles–rubella vaccine among Forcibly Displaced Myanmar Nationals in Bangladesh. *Human Vaccines and Immunotherapeutics*. 2019;15(12): 2882–2886. <https://doi.org/10.1080/21645515.2019.1616502>.
321. Lam E, Al-Tamimi W, Russell SP, Butt MOUI, Blanton C, Musani AS, et al. Oral cholera vaccine coverage during an outbreak and humanitarian Crisis, Iraq, 2015. *Emerging Infectious Diseases*. 2017;23(1): 38–45. <https://doi.org/10.3201/eid2301.160881>.
322. Lubogo M, Mohamed AM, Ali AH, Ali AH, Popal GR, Kiongo D, et al. Oral cholera vaccination coverage in an acute emergency setting in Somalia, 2017. *Vaccine*. 2020;38(October 2017): A141–A147. <https://doi.org/10.1016/j.vaccine.2020.01.015>.

323. Ngwa MC, Alemu W, Okudo I, Owili C, Ugochukwu U, Clement P, et al. The reactive vaccination campaign against cholera emergency in camps for internally displaced persons, Borno, Nigeria, 2017: A two-stage cluster survey. *BMJ Global Health*. 2020;5(6): 1–12. <https://doi.org/10.1136/bmjgh-2020-002431>.
324. Ngwa MC, Wondimagegnehu A, Okudo I, Owili C, Ugochukwu U, Clement P, et al. The multi-sectorial emergency response to a cholera outbreak in Internally Displaced Persons camps in Borno State, Nigeria, 2017. *BMJ Global Health*. 2020;5(1): 1–12. <https://doi.org/10.1136/bmjgh-2019-002000>.
325. Peyraud N, Quéré M, Duc G, Chèvre C, Wanteu T, Reache S, et al. A post-conflict vaccination campaign, central African republic. *Bulletin of the World Health Organization*. 2018;96(8): 540–547. <https://doi.org/10.2471/BLT.17.204321>.
326. Porta MI, Lenglet A, de Weerd S, Crestani R, Sinke R, Frawley MJ, et al. Feasibility of a preventive mass vaccination campaign with two doses of oral cholera vaccine during a humanitarian emergency in South Sudan. *Transactions of the Royal Society of Tropical Medicine and Hygiene*. 2014;108(12): 810–815. <https://doi.org/10.1093/trstmh/tru153>.
327. Sheikh MA, Makokha F, Hussein MA, Mohamed G, Mach O, Humayun K, et al. Combined Use of Inactivated and Oral Poliovirus Vaccines in Refugee Camps and Surrounding Communities — Kenya, December 2013. *MMWR - Morbidity & Mortality Weekly Report*. 2014;63(11): 237–241.
328. M Shuaibu F, Birukila G, Usman S, Mohammed A, Galway M, Corkum M, et al. Mass immunization with inactivated polio vaccine in conflict zones - Experience from Borno and Yobe States, North-Eastern Nigeria. *Journal of Public Health Policy*. 2016;37(1): 36–50. <https://doi.org/10.1057/jphp.2015.34>.
329. Venczel L, Dobbins J, André J, Laender F, Izurieta H, Delorme P, et al. Measles Eradication in the Americas: Experience in Haiti. *The Journal of Infectious Diseases*. 2003;187(s1): S127–S132. <https://doi.org/10.1086/368029>.
330. WHO/GPEI. *The Short Interval Additional Dose (SIAD) - An intensified campaign approach to deliver monovalent Oral Polio Vaccine (mOPV)*. https://polioeradication.org/wp-content/uploads/2017/05/SIAD_Implementation_Guide.pdf
331. Bonfrer I, van de Poel E, van Doorslaer E. The effects of performance incentives on the utilization and quality of maternal and child care in Burundi. *Social Science & Medicine*. 2014;123: 96–104. <https://doi.org/10.1016/j.socscimed.2014.11.004>.
332. Engineer CY, Dale E, Agarwal A, Agarwal A, Alonge O, Edward A, et al. Effectiveness of a pay-for-performance intervention to improve maternal and child health services in Afghanistan: A cluster-randomized trial. *International Journal of Epidemiology*. 2016;45(2): 451–459. <https://doi.org/10.1093/ije/dyv362>.
333. Falisse JB, Ndayishimiye J, Kamenyero V, Bossuyt M. Performance-based financing in the context of selective free health-care: An evaluation of its effects on the use of primary health-care services in Burundi using routine data. *Health Policy and Planning*. 2015;30(10): 1251–1260. <https://doi.org/10.1093/heapol/czu132>.
334. Yehualashet YG, Wadda A, Agblewonu KB, Zhema T, Ibrahim A, Corr A, et al. World health organization's innovative direct disbursement mechanism for payment of grassroots immunization personnel and operations in Nigeria: 2004-2015. *Journal of Infectious Diseases*. 2016;213(Suppl 3): S108–S115. <https://doi.org/10.1093/infdis/jiv485>.
335. Vink M, Upadhaya N, Amin HA, Liwal MG, Siddiqui AM, Naseem M, et al. Does support to Private Health Practitioners increase childhood vaccination coverage? Findings from a comparative study in Afghanistan. *Vaccine*. 2021;39(35): 5007–5014. <https://doi.org/10.1016/j.vaccine.2021.07.018>.
336. Dadari I, Higgins-Steele A, Sharkey A, Charlet D, Shahabuddin A, Nandy R, et al. Pro-equity immunization and health systems strengthening strategies in select Gavi-supported countries. *Vaccine*. 2021;39(17): 2434–2444. <https://doi.org/10.1016/j.vaccine.2021.03.044>.
337. Valadez JJ, Berendes S, Odhiambo J, Vargas W, Devkota B, Lako R, et al. *Is development aid to strengthen health systems during protracted conflict a useful investment? The case of South Sudan, 2011-2015*. *BMJ Global Health*. 2020. p. 2011–2015. <https://doi.org/10.1136/bmjgh-2019-002093>.

338. Edmond K, Yousufi K, Naziri M, Higgins-Steele A, Qadir AQ, Sadat SM, et al. Mobile outreach health services for mothers and children in conflict-affected and remote areas: A population-based study from Afghanistan. *Archives of Disease in Childhood*. 2020;105(1): 18–25. <https://doi.org/10.1136/archdischild-2019-316802>.
339. Ongwae KM, Bawa SB, Shuaib F, Braka F, Corkum M, Isa HK. Use of Dedicated Mobile Teams and Polio Volunteer Community Mobilizers to Increase Access to Zero-Dose Oral Poliovirus Vaccine and Routine Childhood Immunizations in Settlements at High Risk for Polio Transmission in Northern Nigeria. *Journal of Infectious Diseases*. 2017;216: S267–S272. <https://doi.org/10.1093/infdis/jiw520>.
340. Idris IO, Obwoya JG, Tapkigen J, Lamidi SA, Ochagu VA, Abbas K. Impact evaluation of immunisation service integration to nutrition programmes and paediatric outpatient departments of primary healthcare centres in Rumbek East and Rumbek Centre counties of South Sudan. *Family Medicine and Community Health*. 2021;9(3): 1–11. <https://doi.org/10.1136/fmch-2021-001034>.
341. Oladeji O, Campbell P, Jaiswal C, Chamla D, Oladeji B, Ajumara CO, et al. Integrating immunisation services into nutrition sites to improve immunisation status of internally displaced persons' children living in bentiu protection of civilian site, south sudan. *Pan African Medical Journal*. 2019;32: 1–11. <https://doi.org/10.11604/pamj.2019.32.28.15464>.
342. Bawa S, McNab C, Nkwogu L, Braka F, Obinya E, Galway M, et al. Using the polio programme to deliver primary health care in Nigeria: Implementation research. *Bulletin of the World Health Organization*. 2019;97(1): 24–32. <https://doi.org/10.2471/BLT.18.211565>.
343. Habib MA, Soofi S, Cousens S, Anwar S, Haque N ul, Ahmed I, et al. Community engagement and integrated health and polio immunisation campaigns in conflict-affected areas of Pakistan: a cluster randomised controlled trial. *The Lancet Global Health*. 2017;5(6): e593–e603. [https://doi.org/10.1016/S2214-109X\(17\)30184-5](https://doi.org/10.1016/S2214-109X(17)30184-5).
344. Fekadu L, Okeibunor J, Nsubuga P, Marie J, Mkanda P, Mihigo R. Reaching the unreached with polio vaccine and other child survival interventions through partnership with military in Angola. *Vaccine*. 2016;34(43): 5155–5158. <https://doi.org/10.1016/j.vaccine.2016.05.069>.
345. Nkwogu L, Shuaib F, Braka F, Mkanda P, Banda R, Korir C, et al. Impact of engaging security personnel on access and polio immunization outcomes in security-inaccessible areas in Borno state, Nigeria. *BMC Public Health*. 2018;18(Suppl 4). <https://doi.org/10.1186/s12889-018-6188-9>.
346. Arale A, Lutukai M, Mohamed S, Bologna L, Stamidis K v. Preventing importation of poliovirus in the Horn of Africa: The success of the cross-border health initiative in Kenya and Somalia. *American Journal of Tropical Medicine and Hygiene*. 2019;101(4): 100–106. <https://doi.org/10.4269/ajtmh.19-0040>.
347. Duru JI, Usman S, Adeosun O, Stamidis K v, Bologna L. Contributions of volunteer community mobilizers to polio eradication in Nigeria: The Experiences of Non-governmental and Civil Society Organizations. *American Journal of Tropical Medicine and Hygiene*. 2019;101(4): 74–84. <https://doi.org/10.4269/ajtmh.19-0068>.
348. Yehualashet YG, Mkanda P, Gasasira A, Erbetto T, Onimisi A, Horton J, et al. Strategic engagement of technical surge capacity for intensified polio eradication initiative in Nigeria, 2012-2015. *Journal of Infectious Diseases*. 2016;213(Suppl 3): S116–S123. <https://doi.org/10.1093/infdis/jiv494>.
349. Oteri J, Idi Hussaini M, Bawa S, Ibizugbe S, Lambo K, Mogeckwu F, et al. Application of the Geographic Information System (GIS) in immunisation service delivery; its use in the 2017/2018 measles vaccination campaign in Nigeria. *Vaccine*. 2021;39(Suppl 3): C29–C37. <https://doi.org/10.1016/j.vaccine.2021.01.021>.
350. Rainey JJ, Sugerman D, Brennan M, Cadet JR, Ernsly J, Lacapère F, et al. Rapid monitoring in vaccination campaigns during emergencies: the post-earthquake campaign in Haiti. *Bulletin of the World Health Organization*. 2013;91(12): 957–962. <https://doi.org/10.2471/blt.12.117044>.
351. Aradhi AAM, Hasson LM, Hameed IM. Polio Outbreak Response; Evaluation of Acute Flaccid Paralysis Surveillance in Karbala, Iraq Abstract. *International Journal of Preventive Medicine*. 2020;11(131). https://doi.org/10.4103/ijpvm.IJPVM_128_17.
352. Hammanyero KI, Bawa S, Braka F, Basse BE, Fatiregun A, Warigon C, et al. *Lessons learnt from implementing community engagement interventions in mobile hard-to-reach (HTR) projects in Nigeria, 2014-2015*. BMC Public Health. 2018. <https://doi.org/10.1186/s12889-018-6193-z>.

353. Korir C, Shuaib F, Adamu U, Bawa S, Musa A, Bashir A, et al. Targeting the last polio sanctuaries with Directly Observed Oral Polio Vaccination (DOPV) in northern Nigeria, (2014–2016). *BMC Public Health*. 2018;18(S4): 1314. <https://doi.org/10.1186/s12889-018-6182-2>.
354. Usman S, Bologna L, Stamidis K v. The core group partners project in North East Nigeria: Community engagement strategies to combat skepticism and build trust for vaccine acceptance. *American Journal of Tropical Medicine and Hygiene*. 2019;101(4): 68–73. <https://doi.org/10.4269/ajtmh.19-0143>.
355. Warigon C, Mkanda P, Muhammed A, Etsano A, Korir C, Bawa S, et al. Demand creation for polio vaccine in persistently poor-performing communities of Northern Nigeria: 2013-2014. *Journal of Infectious Diseases*. 2016;213(Suppl 3): S79–S85. <https://doi.org/10.1093/infdis/jiv511>.
356. Kamadjeu R, Mahamud A, Webeck J, Baranyikwa MT, Chatterjee A, Bile YN, et al. Polio Outbreak Investigation and Response in Somalia, 2013. *Journal of Infectious Diseases*. 2014;210(suppl 1): S181–S186. <https://doi.org/10.1093/infdis/jiu453>.
357. Khetsuriani N, Perehinets I, Nitzan D, Popovic D, Moran T, Allahverdiyeva V, et al. Responding to a cVDPV1 outbreak in Ukraine: Implications, challenges and opportunities. *Vaccine*. 2017;35(36): 4769–4776. <https://doi.org/10.1016/j.vaccine.2017.04.036>.
358. Mirza IR, Kamadjeu R, Assegid K, Mulugeta A. Somalia: Supporting the child survival agenda when routine health service is broken. *Journal of Infectious Diseases*. 2012;205(SUPPL. 1). <https://doi.org/10.1093/infdis/jir776>.
359. UNICEF Lebanon. *Accelerated Immunization Activities Evaluation - final report*. 2021.
360. Haddison EC, Ngono D, Kouamen GT, Kagina BM. Successful polio supplementary immunisation activities in a security compromised zone – Experiences from the Southwest region of Cameroon. *Vaccine*. 2018;36(46): 6961–6967. <https://doi.org/10.1016/j.vaccine.2018.10.004>.
361. Rouzier V, Severe K, Juste MAJ, Peck M, Perodin C, Severe P, et al. Cholera vaccination in Urban Haiti. *American Journal of Tropical Medicine and Hygiene*. 2013;89(4): 671–681. <https://doi.org/10.4269/ajtmh.13-0171>.
362. Meteke S, Stefopoulos M, Als D, Gaffey MF, Kamali M, Siddiqui FJ, et al. Delivering infectious disease interventions to women and children in conflict settings: A systematic review. *BMJ Global Health*. 2020;5: 1–17. <https://doi.org/10.1136/bmjgh-2019-001967>.
363. Oyo-Ita A, Wiysonge CS, Oringanje C, Nwachukwu CE, Oduwole O, Meremikwu MM. Interventions for improving coverage of childhood immunisation in low- and middle-income countries. *Cochrane Database of Systematic Reviews*. 2016;(7). <https://doi.org/10.1002/14651858.CD008145.pub3>.
364. Rull M, Masson S, Peyraud N, Simonelli M, Ventura A, Dorion C, et al. The new WHO decision-making framework on vaccine use in acute humanitarian emergencies: MSF experience in Minkaman, South Sudan. *Conflict and health*. 2018;12: 11. <https://doi.org/10.1186/s13031-018-0147-z>.
365. Chakrabarti A, Grépin KA, Helleringer S. The impact of supplementary immunization activities on routine vaccination coverage: An instrumental variable analysis in five low-income countries. Gopichandran V (ed.) *PLOS ONE*. 2019;14(2): e0212049. <https://doi.org/10.1371/journal.pone.0212049>.
366. Portnoy A, Jit M, Helleringer S, Verguet S. Impact of measles supplementary immunization activities on reaching children missed by routine programs. *Vaccine*. 2018;36(1): 170–178. <https://doi.org/10.1016/j.vaccine.2017.10.080>.
367. Abson DJ, Fischer J, Leventon J, Newig J, Schomerus T, Vilsmaier U, et al. Leverage points for sustainability transformation. *Ambio*. 2017;46(1): 30–39. <https://doi.org/10.1007/s13280-016-0800-y>.
368. Bloom G, Wilkinson A, Standing H, Lucas H. Engaging with Health Markets in Low and Middle-Income Countries. *IDS Working Papers*. 2014;2014(443): 1–28. <https://doi.org/10.1111/j.2040-0209.2014.00443.x>.
369. Tsofa B, Goodman C, Gilson L, Molyneux S. Devolution and its effects on health workforce and commodities management – early implementation experiences in Kilifi County, Kenya. *International Journal for Equity in Health*. 2017;16(1): 169. <https://doi.org/10.1186/s12939-017-0663-2>.

370. McCollum R, Otiso L, Taegtmeier M, Limato R, Theobald S. Health system governance following devolution: comparing experiences of decentralisation in Kenya and Indonesia. *BMJ Global Health*. 2018;3(5): e000939. <https://doi.org/10.1136/bmjgh-2018-000939>.
371. Tsofa B, Molyneux S, Gilson L, Goodman C. How does decentralisation affect health sector planning and financial management? a case study of early effects of devolution in Kilifi County, Kenya. *International Journal for Equity in Health*. 2017;16(1): 151. <https://doi.org/10.1186/s12939-017-0649-0>.
372. Lembani M, de Pinho H, Delobelle P, Zarowsky C, Mathole T, Ager A. Understanding key drivers of performance in the provision of maternal health services in eastern cape, South Africa: a systems analysis using group model building. *BMC Health Services Research*. 2018;18(1): 912. <https://doi.org/10.1186/s12913-018-3726-1>.
373. Wolstenholme EF. Towards the definition and use of a core set of archetypal structures in system dynamics. *System Dynamics Review*. 2003;19(1): 7–26. <https://doi.org/10.1002/sdr.259>.
374. Sterman J. System dynamics at sixty: the path forward. *System Dynamics Review*. 2018;34(1–2): 5–47. <https://doi.org/10.1002/sdr.1601>.
375. Forrester JW. System dynamics, systems thinking, and soft OR. *System Dynamics Review*. 1994;10(2–3): 245–256. <https://doi.org/10.1002/sdr.4260100211>.
376. Helfgott A. Operationalising systemic resilience. *European Journal of Operational Research*. 2018;268(3): 852–864. <https://doi.org/10.1016/j.ejor.2017.11.056>.
377. Hutchinson E, Balabanova D, McKee M. We need to talk about corruption in health systems. *International Journal of Health Policy and Management*. 2019;8(4): 191–194. <https://doi.org/10.15171/IJHPM.2018.123>.
378. Naher N, Hoque R, Hassan MS, Balabanova D, Adams AM, Ahmed SM. The influence of corruption and governance in the delivery of frontline health care services in the public sector: a scoping review of current and future prospects in low and middle-income countries of south and south-east Asia. *BMC Public Health*. 2020;20(1): 880. <https://doi.org/10.1186/s12889-020-08975-0>.
379. Doocy S, Lyles E, Hanquart B, Woodman M, Amara A, Aljunid S, et al. Prevalence, care-seeking, and health service utilization for non-communicable diseases among Syrian refugees and host communities in Lebanon. *Conflict and Health*. 2016;10(1): 21. <https://doi.org/10.1186/s13031-016-0088-3>.
380. Lane DC. What we talk about when we talk about 'systems thinking'. *Journal of the Operational Research Society*. 2016;67(3): 527–528. <https://doi.org/10.1057/jors.2015.10>.
381. Richardson GP. Problems with causal-loop diagrams. *System Dynamics Review*. 1986;2(2): 158–170. <https://doi.org/10.1002/sdr.4260020207>.
382. Ismail SA, Abbara A, Collin SM, Orcutt M, Coutts AP, Maziak W, et al. Communicable disease surveillance and control in the context of conflict and mass displacement in Syria. *International Journal of Infectious Diseases*. 2016;47: 15–22. <https://doi.org/10.1016/j.ijid.2016.05.011>.
383. Chen B, Cammett M. Informal politics and inequity of access to health care in Lebanon. *International journal for equity in health*. 2012;11: 23. <https://doi.org/10.1186/1475-9276-11-23>.
384. Cammett MC. *Compassionate communalism: welfare and sectarianism in Lebanon*. New York: Cornell University Press; 2014.
385. Salti N, Chaaban J, Raad F. Health equity in Lebanon: a microeconomic analysis. *International Journal for Equity in Health*. 2010;9(1): 11. <https://doi.org/10.1186/1475-9276-9-11>.
386. Salti N, Chaaban J. The role of sectarianism in the allocation of public expenditure in postwar Lebanon. *International Journal of Middle East Studies*. 2010;42(4): 637–655. <https://doi.org/10.1017/S0020743810000851>.
387. Bhandari S, Alonge O. Measuring the resilience of health systems in low- and middle-income countries: a focus on community resilience. *Health Research Policy and Systems*. 2020;18(1): 81. <https://doi.org/10.1186/s12961-020-00594-w>.
388. Martineau FP. People-centred health systems: Building more resilient health systems in the wake of the Ebola crisis. *International Health*. 2016;8(5): 307–309. <https://doi.org/10.1093/inthealth/ihw029>.

389. Reuters. Death toll from sinking of Lebanon boat rises to 94. *Observer Newspaper*. 2022. <https://www.theguardian.com/world/2022/sep/24/lebanon-migrant-boat-sinking-syria-death-toll> [Accessed 30th November 2022].
390. Sanderson C, Gruen R. *Analytical Models for Decision Making*. 2nd Edition. London: McGraw Hill; 2015.
391. Peters DH. The application of systems thinking in health: why use systems thinking? *Health Research Policy and Systems*. 2014;12(1): 51. <https://doi.org/10.1186/1478-4505-12-51>.
392. Reynolds M, Sarriot E, Swanson RC, Rusoja E. Navigating systems ideas for health practice: Towards a common learning device. *Journal of Evaluation in Clinical Practice*. 2018;24(3): 619–628. <https://doi.org/10.1111/jep.12872>.
393. Homer JB, Hirsch GB. System dynamics modeling for public health: background and opportunities. *American journal of public health*. 2006;96(3): 452–458. <https://doi.org/10.2105/AJPH.2005.062059>.
394. Mashayekhi AN, Ghili S. System dynamics problem definition as an evolutionary process using the concept of ambiguity. *System Dynamics Review*. 2012;28(2): 182–198. <https://doi.org/10.1002/sdr>.
395. Bérard C. Group model building using system dynamics: An analysis of methodological frameworks. *Electronic Journal of Business Research Methods*. 2010;8(1): 35–45.
396. Levin A, Kaddar M. Role of the private sector in the provision of immunization services in low- and middle-income countries. *Health Policy and Planning*. 2011;26(Suppl. 1): i4–i12. <https://doi.org/10.1093/heapol/czr037>.
397. Bertone MP, Jowett M, Dale E, Witter S. Health financing in fragile and conflict-affected settings: What do we know, seven years on? *Social Science & Medicine*. 2019;232: 209–219. <https://doi.org/10.1016/j.socscimed.2019.04.019>.
398. WHO. *Microplanning for immunization service delivery using the RED strategy*. World Health Organization. Geneva; 2009. <https://apps.who.int/iris/handle/10665/70450> [Accessed 1st December 2022].
399. WHO. *A guide for conducting an Expanded Programme on Immunization (EPI) Review*. Geneva: World Health Organisation; 2017. <https://apps.who.int/iris/handle/10665/259960> [Accessed 1st December 2022].
400. Sodha S v, Dietz V. Strengthening routine immunization systems to improve global vaccination coverage. *British Medical Bulletin*. 2015;113(1): 5–14. <https://doi.org/10.1093/bmb/ldv001>.
401. Rechel B, Richardson E, McKee M. *The organization and delivery of vaccination services*. Copenhagen: European Observatory on Health Systems and Policies; 2018. <https://apps.who.int/iris/handle/10665/330345> [Accessed 1st December 2022].
402. Faour MA. Religion, demography, and politics in Lebanon. *Middle Eastern Studies*. 2007;43(6): 909–921. <https://doi.org/10.1080/00263200701568279>.
403. UNHCR. *Refugee Statistics - data finder*. <https://www.unhcr.org/refugee-statistics/download/?url=2bxU2f> [Accessed 30th November 2022].
404. Robertson T, Weiss W, Doocy S, Team TLHAS, Doocy S, Robertson T, et al. Challenges in Estimating Vaccine Coverage in Refugee and Displaced Populations: Results From Household Surveys in Jordan and Lebanon. *Vaccines*. 2017;5(3): 22. <https://doi.org/10.3390/vaccines5030022>.
405. Rossi R, Assaad R, Rebeschini A, Hamadeh R. Vaccination Coverage Cluster Surveys in Middle Dreib – Akkar, Lebanon: Comparison of Vaccination Coverage in Children Aged 12-59 Months Pre- and Post-Vaccination Campaign. Borrow R (ed.) *PLOS ONE*. 2016;11(12): e0168145. <https://doi.org/10.1371/journal.pone.0168145>.
406. WHO EMRO. *Measles situation in Lebanon*. Cairo: WHO EMRO; 2018. http://www.emro.who.int/images/stories/lebanon/measles_situation.pdf [Accessed 1st December 2022].
407. Lazzarini P. *Resident/Humanitarian Coordinator Report on the Use of CERF Funds: Lebanon Rapid Response Measles Outbreak 2018*. Beirut; 2018. https://cerf.un.org/sites/default/files/resources/18-RR-LBN-30469-NR01_Lebanon_RCHC.Report.pdf [Accessed 1st December 2022].

408. UNHCR. *Uganda Comprehensive Refugee Response Portal*. <https://data.unhcr.org/en/country/uga> [Accessed 30th November 2022].
409. International Refugee Rights Initiative. *Uganda's refugee policies: The history, the politics, the way forward*. International Refugee Rights Initiative. Kampala; 2018. <http://refugee-rights.org/uganda-refugee-policies-the-history-the-politics-the-way-forward/> [Accessed 1st December 2022].
410. Republic of Uganda Ministry of Health. *Health Sector Integrated Refugee Response Plan 2019-24*. Kampala: Republic of Uganda; 2019. <https://www.health.go.ug/cause/health-sector-integrated-refugee-response-plan/> [Accessed 1st December 2022].
411. Guthrie T, Zikusooka C, Kwesiga B, Abewe C, Lagony S, Schutte C, et al. *Costing and Financing Analyses of Routine Immunization in Uganda*. 2014. <https://static1.squarespace.com/static/556deb8ee4b08a534b8360e7/t/5596fa4ae4b07b7dda4dd04d/1435957834829/UGANDA+Immunization+Costing+Report+1+December+14+submitted+FINAL+update+15+12+14+errors.pdf>
412. Uganda NITAG. *Prioritisation of vaccine introduction in the UNEPI*. Kampala: Uganda National Academy of Sciences; 2017. <https://www.nitag-resource.org/resources/prioritisation-vaccine-introduction-unepi> [Accessed 1st December 2022].
413. Gavi. *Uganda Fact Sheet*. <https://www.gavi.org/programmes-impact/country-hub/africa/uganda> [Accessed 30th November 2022].
414. UNHCR. *Uganda Country Refugee Response Plan*. The UN Refugee Agency. Kampala: UNHCR; 2019. [http://reporting.unhcr.org/sites/default/files/Uganda Country RRP 2019-20 %28January 2019%29.pdf](http://reporting.unhcr.org/sites/default/files/Uganda%20Country%20RRP%202019-20%20January%202019.pdf)
415. Komakech H, Atuyambe L, Orach CG. Integration of health services, access and utilization by refugees and host populations in West Nile districts, Uganda. *Conflict and Health*. 2019;13(1): 1. <https://doi.org/10.1186/s13031-018-0184-7>.
416. WHO. *The elimination of user fees in Uganda: impact on utilization and catastrophic World Health Organization*. Kampala: World Health Organisation; 2005. http://www.who.int/health_financing/documents/dp_e_05_4-user_fee_elimination_uganda.pdf
417. Kasozi J. Access to Health Care by Urban Refugees and Surrounding Host Population in Uganda. *World Journal of Public Health*. 2018;3(2): 32. <https://doi.org/10.11648/j.wjph.20180302.11>.
418. UNICEF, EPRC, University of Cardiff. *Child Poverty and Deprivation in Refugee-Hosting Areas Evidence from Uganda*. 2018. <https://www.unicef.org/uganda/ChildPovertyRefugees-FINAL-Lores.pdf>
419. Government of Uganda. *The Immunisation Act, 2017*. [https://ulii.org/ug/legislation/act/2017/7/Immunisation Act 7 2017.pdf](https://ulii.org/ug/legislation/act/2017/7/Immunisation%20Act%207%202017.pdf) [Accessed 30th November 2022].
420. Reynolds M, Wilding H. Boundary critique: an approach for framing methodological design. In: de Savigny D, Blanchet K, Adam T (eds.) *Applied Systems Thinking for Health Systems Research*. London: McGraw-Hill Education (UK); 2017. p. 38–56.
421. Ulrich W, Reynolds M. Critical Systems Heuristics: The Idea and Practice of Boundary Critique. In: *Systems Approaches to Making Change: A Practical Guide*. 2020. <https://doi.org/10.1007/978-1-4471-7472-1>.
422. Kotiadis K. Soft systems methodology: an approach for stakeholder and research reflection on a problem. In: Savigny D de, Blanchet K, Adam T (eds.) *Applied Systems Thinking for Health Systems Research*. London: McGraw-Hill Education (UK); 2017. p. 57–75.

APPENDICES

Appendix 1: A general introduction to systems methods

A1.1 Overview of methods for framing the system, and problem, for investigation

While a panoply of analytical decision-support tools now exists in health, many of these (e.g., the Strategic Choice Approach, or Multi-Criteria Decision Analysis) assume a reasonable degree of consensus on the part of stakeholders regarding the nature of “the problem” and the range of options available to address it (390). The focus of analysis is then on rational approaches to deciding between defined policy options, based on evidence assessment and potentially quantitative analysis of likely impact. There is much less methodological certainty concerning best approaches in instances where fundamental questions remain regarding problem definition and boundaries. Chapters 1 and 2 illustrated some of the ways in which such consensus is absent for many questions concerning health service delivery in humanitarian settings in general, and childhood vaccination delivery in particular, emphasising core challenges in defining system characteristics and boundaries, and even what is meant by the term “shock”.

Conventional analytical decision-support tools also frequently assume linearity in system behaviour (or try to find linear approximations to non-linear system behaviour) – an assumption that rarely applies to system behaviour in reality. For better approximations to the non-linear behaviours that social systems actually display, we need to turn instead to a cluster of analytical techniques that have emerged from systems science, including approaches focused on exploring the nature of networking between system actors (e.g. Social Network Analysis, or SNA), the effects of causal relationships and feedback loops on system behaviour (system dynamics modelling, or SDM), or those that emphasise the adaptability of individual system actors (e.g. Agent Based Modelling, or ABM) (97).

In domains where there are fundamental uncertainties over problem definition, we can look to a further set of consensus-building tools, to help delineate system characteristics and objectives for decision support work. Table 17 outlines some of the key methods contributing to system boundary delineation, analysing relationships between stakeholders, and arriving at consensus on system problems as a precursor to quantitative system modelling, or *ex ante* evaluation of interventions. These are reliant, for the most part, on qualitative research methods (97). The table also indicates the analytical functions that each of these methods can perform, ranging from simply describing systems and boundaries, through to formally supporting decision-making through negotiation between stakeholders.

Analytical function Systems thinking approach	Describe the system and its boundaries	Analyse stakeholder relationships	Identify and build understanding of system problems	Identify potential policy and programme solutions	Support decision-making through negotiation
Boundary critique ²¹					
Soft systems methodology ²²					
Causal loop diagramming ²³					
Network analysis ²⁴					
Process mapping ²⁵					

Table 17. Qualitative methods for analysis and boundary definition of complex systems.

Each of these approaches carries strengths and weaknesses for problem-framing and boundary definition. A detailed, comparative assessment of these approaches is beyond the scope of this appendix, but for the purposes of this thesis, an analytical approach is needed that blends aspects of:

1. Boundary definition;
2. Building understanding of system problems – in particular, of “pinch points” in vaccination delivery which underpin performance problems and which may be amenable to improvement or change; and

²¹ Boundary critique has been described as a “reflective systems approach” to encourage researcher reflection on problem boundary definitions, and why certain boundary judgements are made by researchers rather than others. In particular, through linked approaches such as Critical Systems Heuristics (CSH), it promotes a political economy perspective to clarify the reasons why researchers judge that certain stakeholders, stakes or issues should be defined as “inside” or “outside” the boundaries of a problem of interest (420,421).

²² Soft Systems Methodology (SSM) provides a structured process for problem definition, stakeholder engagement in model development, and a framework for discussion of potential solutions. There is a degree of flexibility in the specific approaches used to support this, but the emphasis of SSM is on encouraging participants to consider differences between the current (problematic) situation and an alternative, ideal-type future scenario, and then the actions that may be required to move from one to the other. Common applications of SSM include its use as a precursor to formal quantitative modelling through, for example, discrete event simulation, by helping to delineate the problem which is then addressed through modelling (422).

²³ Causal loop diagramming describes the qualitative components of system dynamics modelling – outlined in further detail in section 4.1.2. It involves the elucidation of variables relevant to a problem of interest, and the mapping out of causal links between these.

²⁴ Network analysis focuses on mapping out key actors in a system and relations between these, with a focus on information exchange. Social network analysis is described in more detail in section 4.1.2.

²⁵ Process mapping is a systematic approach for the delineation of important system processes (in an end-to-end way) to identify potential bottlenecks affecting system performance. Although there is some scope for incorporation of feedbacks within the maps, this approach by definition assumes a degree of linearity in processes leading to key service outcomes.

3. Supporting decision-making through construction of shared understanding of system problems and leverage points to drive service delivery improvements.

These requirements preclude the use of some problem framing approaches (e.g., boundary critique, network analysis), and underscore the potential value of others (e.g., causal loop diagramming).²⁶

A1.2 Understanding dynamic change within systems: spectrum of possible approaches

The purpose of this thesis is not merely to *describe* vaccination delivery systems and relationships between stakeholders within them, but to support decision-making through the application of systems methods. A broad set of systems methods and techniques has emerged over the past 50 years that seek to strengthen understanding of complex problems, and the value of systems thinking approaches for analysing health systems is increasingly recognised (391). These approaches acknowledge the importance of context and emphasise relationships and feedback between elements of a system and how these evolve over time (96,97,392,393). They also identify particular kinds of behaviour as characteristic of complex systems, notably including emergence i.e., novel behaviours generated by the combination of elements in a system, rather than by individual elements themselves (95).

When modelling dynamic systems, the choice of method depends on the centrality or otherwise of system elements (or agents) to the analysis, and, if they are deemed to be important to understanding the problem at hand, the extent to which they can change over time (see Table 18) (282). Where agent characteristics are similar or have no direct effect on system behaviour, but linkages between those elements are thought to be important, SNA is the preferred approach. Where elements differ in important ways, it is the nature of dynamic interactions between these elements (agents) and the environment that matter – and ABM is the preferred approach (192). If neither of these conditions are satisfied, and dynamic behaviour within the system is regarded as more important, SDM is preferred (see Table 18 – adapted from (282)) (97).

²⁶ Although a full discussion of epistemological considerations in selection of systems methods is beyond the scope of this thesis, there are also important reasons why the combined use of approaches such as boundary critique or SSM with other systems methods might not be appropriate – linked to the disciplinary and philosophical traditions from which each originates. Boundary critique and SSM both originate from what has been termed the “critical systems” tradition (after Peter Checkland and others) and are subjectivist in orientation. The most important hallmark of this tradition is a belief that relevant methods do not, or cannot, describe systems as real, empirical objects of enquiry – in contrast to system dynamics. The extent to which subjectivist problem structuring methods such as SSM can be combined with “hard” methods such as system dynamics remains a topic of some controversy in the academic literature on systems approaches (420,422).

		Have characteristics of individual agents been demonstrated to be essential to understanding the problem?	
		<i>No (homogeneity of system elements)</i>	<i>Yes (heterogeneity of system elements)</i>
Has the social network linking elements (agents) been demonstrated to be essential to understanding the problem?	<i>Yes (compartments matter)</i>	Social network analysis	Agent-based modelling (ABM)
	<i>No (there is perfect mixing between compartments)</i>	Differential equation modelling (principally, system dynamics or SDM)	

Table 18. Matrix for selection of appropriate complex systems analysis methods.

An important function of the preliminary scoping study for this research project (see **Appendix 2**) was to inform the selection of which systems method to apply in this project. This selection was also informed to some degree by the results of paper 1. Initial scoping work suggested that a multi-level view of dynamics affecting vaccination coverage was needed, and because neither the nature of system agents nor network effects offered a full explanation for observed patterns of behaviour in the vaccination delivery system in Lebanon in response to the initial shock (population movement), system dynamics was selected as the preferred approach.

A1.3 Justification for the overarching methodological approach for the research project

This research project employed a qualitative, mixed-methods approach with a particular emphasis on SDM, to understand vaccination delivery system responses to shocks. As we have seen, systems thinking approaches allow for the complexity of relationships between elements of a system to be unpacked, recognising the non-linear nature of system behaviour over time, and the potential for unintended consequences when new interventions or contextual changes are applied to them, in contrast to conventional evaluation approaches (93,94).

The project applied SDM in preference to other systems thinking methods (see sections A1.1 and A1.2 for an overview of these) principally because of the flexibility and range that SDM offers in addressing everything from boundary definition and problem identification (through stakeholder engagement in causal loop diagramming) through to identification and testing of potential solutions (through quantitative system dynamics modelling). None of the other systems thinking methods described above offer comparable analytical range. SDM has three additional advantages when compared with other relevant systems thinking methods such as SNA and ABM (390):

1. Macro-level perspective: SDM typically models systems at aggregate level, focusing on the effects of feedback loops on system behaviour over time in response to disturbances. This is in contrast to ABM which emphasises the characteristics of individual agents (usually individual people) within a system at micro-level;
2. Handling of uncertainty: SD models are models of *decision rules* governing relationships between system elements, rather than models that privilege data *per se* (118). SD simulation models can be high fidelity, data-intensive ones that allow for prediction of actual trends (a function for which they have routinely been used as part of the COVID-19 response in the UK and other countries, for example), or higher-order policy models that provide general projections of system behaviour. SD policy models typically have less stringent data input requirements in contexts where data is in short supply than SNA. This is a considerable advantage in humanitarian contexts where data poverty is a common hallmark (93,95);
3. Modelling of dynamic change, flows and feedback loops between elements in a system: SDM emphasises linkages between system elements and both intended and unintended consequences of system change(s). This has important advantages in investigating the effects of system stressors or disturbances in humanitarian settings, by comparison with SNA, where the emphasis in modelling is on network structure alone.

While there is burgeoning interest in systems science approaches in health (95–97), and acknowledgement that they have the potential to significantly improve *ex ante* and *ex post* evaluation of policy and programme designs (93), empirical applications of systems modelling methods in LMICs have been relatively few (62,81,98–106). Only a handful of studies using systems modelling approaches empirically in crisis-affected settings have been conducted (spanning all sectors) (81,107–109) – just one of which explicitly addressed vaccination delivery (81).

Nevertheless, some assumptions inherent to SDM introduce limitations especially when applied to modelling of social systems. The most important of these is the centrality of what Richardson terms “the endogenous view” in system dynamics: specifically, the assumption that all significant behaviour relevant to the problem is driven by feedbacks and time or material delays within the system’s boundaries (112). In this sense, SDM models closed systems (with behaviours characteristic of complex *physical* systems, or CPS). Social systems are, by contrast, predominantly complex *adaptive* systems (CAS) with open boundaries, and with behaviours that may be heavily influenced by actors outside those boundaries or by environmental factors (124). From a quantitative modelling perspective, modelling CAS typically precludes the use of ordinary or partial differential equations that underpin SDM, and

modelling approaches such as ABM or communication network modelling are typically preferred (3). For CPS, differential equation-based modelling methods – of which system dynamics modelling (SDM) is the best recognised – are appropriate.

A fundamental challenge in analysis of systems is that is often impossible to say with certainty whether the system behaviours are predominantly endogenously or exogenously driven. In Richardson's view, adopting an endogenous view can be likened to a wager in which the modeller assumes endogeneity because assuming an exogenous state of affairs means acknowledging limited control over mechanisms to achieve change (112). In the context of this study, an endogenous view allows us to focus on aspects of vaccination delivery system behaviour that may be amenable to change through policy or other means.

It is also the case, however, that humanitarian settings are unusually penetrated from a governance perspective. In particular, dynamics in humanitarian settings may be subject to changing contextual features including the motivations and actors of international actors such as donor organisations, the drivers of which lie well outside the boundaries of problem focused narrowly on national health service delivery. For this reason, the central methodological thread of the research project (SDM) in study 1 was complemented by a more conventional qualitative analysis (study 2) focusing on the broader governance context in Lebanon within which childhood vaccination delivery has been embedded. Further justification of the methodological approaches employed in each of the studies in this thesis are given in Chapter 4.

Appendix 2: Scoping study methodology and results

This appendix sets out results from a preliminary scoping study carried out in 2018 and 2019 to set the terms for the research project and to help identify appropriate methods and data collection approaches. Results span Lebanon and, in addition, Uganda – the site for a second case study intended to inform an assessment of the generalisability of findings from the main work in Lebanon. Work in Uganda is ongoing and for this reason results are not reported in the thesis. Findings from the scoping study inform the problem statement and reference modes set out in section 1.5, and the aims and objectives in section 1.6.

Findings reported below reflect the period in which the scoping study was conducted. They do not take account of the most recent changes in Lebanon, for example, nor for the impact of the COVID-19 pandemic on either of the study settings – all of which occurred after the scoping study was completed.

A2.1 Theoretical approach to problem articulation

The scoping study focused on defining the problem to be addressed. Although arguably the most important phase of any research project using systems thinking approaches, there is little consensus in the systems science literature on preferred approaches to problem articulation. Approaches ranging from established decision support methods such as Strategic Options Development and Analysis (SODA), through to network analysis, boundary critique or soft systems methodology (SSM) have been advanced depending on whether the emphasis is on understanding system problems, relationships between key stakeholders, or other practical considerations (97,390,394,395).

A composite set of methods was therefore used to [1] define the problem of interest, and [2] determine the appropriate methodological approach for investigating it. Additional findings from the scoping study (concerning model boundaries, time horizons and so forth) are summarised in section 1.4 in the main report.

A2.2 Scoping study methodology

The scoping study used a mixed methods approach, triangulating data from multiple sources in three steps as outlined in the table below. Details of approaches and findings under each step are described in the sections that follow.

Step	Inputs	Methods employed	Outputs
1 – mixed methods subject-	<ul style="list-style-type: none"> Peer-reviewed and non-peer reviewed literature 	<ul style="list-style-type: none"> Thematic analysis of literature Thematic analysis of discussion notes 	Problem identification

area analysis	<ul style="list-style-type: none"> • Exploratory discussions with a selection of global vaccination delivery and financing stakeholders 		
2 – mixed methods country case studies	<ul style="list-style-type: none"> • Peer-reviewed and non-peer reviewed literature from Lebanon and Uganda • Exploratory stakeholder discussions • Audit of the nature and availability of data on routine vaccination delivery in Lebanon and Uganda 	Case studies (following the selection procedure outlined above)	Problem identification
3 – synthesis	<ul style="list-style-type: none"> • Thematic codes • Secondary data from publicly available sources 	<ul style="list-style-type: none"> • Review of thematic coding • Descriptive analysis of statistics 	<ul style="list-style-type: none"> • Working problem definition • Selection of modelling methodology

Table 19. Steps in the scoping review carried out to determine problem definition for the study.

A2.3 Scoping study results

A2.3.1 Step 1: mixed methods subject-area analysis

This section describes the results of a narrative review of peer- and non-peer reviewed literatures on vaccination delivery systems and determinants of vaccination coverage in LMICs including those affected by humanitarian crises. Exploratory discussions also took place with stakeholders involved in policy development and implementation for vaccination delivery in crises at a global level, including representatives from UNICEF with responsibility respectively for general aspects of humanitarian response (as part of the Emergency Response Team based in New York), immunization delivery in general, and supply chain management specifically, and from the Department of Immunization, Vaccines and Biologicals at WHO, which has an important role in norm-setting and guideline development for immunization delivery globally.

If we understand the goal of routine vaccination delivery as ensuring enhanced population-level immunity to key communicable diseases, and at a more proximate level, population vaccination coverage, then a broad body of evidence now exists across high, middle- and low-income settings describing key determinants of coverage – including for countries in crisis (1,118,119 - among a number of other studies). This literature distinguishes:

- *Demand* for vaccination, in turn shaped by a range of interlinked factors spanning popular perceptions of vaccine effectiveness, concerns over potential harms, and other factors;
- *Supply* of vaccination, spanning aspects of both community access, and facility and healthcare worker (HCW) readiness to administer products, as well as overarching system features including financing and governance.

A2.3.1.1 Drivers of demand for, and supply of, vaccinations

A recent systematic review of evidence from LMICs identifies the decision to vaccinate as the product of favourable population attitudes, pro-vaccination norms in society at large, and individuals' or families' perceived control (or self-efficacy) over the process of vaccination delivery (42). These three normative drivers of demand are underpinned by a host of factors, operating at a number of levels. Societal norms around vaccination, for example, may be influenced by factors including population awareness of the effectiveness of vaccination, perceived safety of different products and popular perceptions of need, as well as the views and influence of informal healthcare providers in LMIC settings (62) – and in crisis-affected settings especially, by trust in services (63,64). A large body of work emphasises the importance of wider determinants of vaccination uptake, including family socioeconomic status, levels of maternal education and ethnicity (65).

Vaccination supply, on the other hand encompasses factors including facility readiness, community access to facilities and HCWs and global considerations such as financing and governance. Facility readiness spans local infrastructure considerations (such as storage capacity, stock and flow awareness, inventory management and waste disposal), human resource considerations (including workforce numbers and training), but is also influenced by meso-level factors (including product distribution methods and equipment) and macro-level factors (including financing, leadership and degrees of political commitment to vaccination) (42). To these may be added system factors including pluralism in vaccine providers, and pathway or service-delivery questions such the prevalence of out-of-hospital births – which may influence the extent to which newborns receive post-delivery follow-up services including routine vaccinations (65). In many low- and middle-income settings, the private sector has a prominent role in delivering EPI vaccinations – which frequently expands in crises (396,397).

There can be specific challenges to vaccine delivery in crisis settings, including disruptions to financing flows and supply chains, loss of qualified staff due to death and/or displacement, and outright destruction of health facilities. Factors emphasised during exploratory stakeholder discussions included competing stakeholder agendas, the challenge of maintaining cold chains especially in remote and rural areas into which initial displacements frequently occur in crises, lack of robust health intelligence in contexts featuring mobile populations, and financing shortfalls especially in the growing number of middle-income countries now affected by crises but ineligible for funding support from Gavi. Stakeholders also emphasised that demand dynamics can change in important ways in crises, and that early and intensive community engagement is often key in minimising disruption to vaccination coverage in these settings.

Adaptive approaches to maintaining vaccination coverage in crises include negotiating secure physical access, outreach campaigns, and even “barrier” methods in which VPD transmission is contained by vaccinating populations around the periphery of areas that are difficult to access (64). A body of recent work has considered the potential of flexible dosing and administration schedules (47,64), and prioritisation of different antigens (83) to improve coverage in areas where insecurity or other physical access barriers may preclude delivery of full or optimal vaccination courses – usually in the acute phase of humanitarian crises.

[A2.3.1.2 Vaccination delivery system components and system strengthening interventions](#)

A predominant focus of the literature cited above is on individual behavioural, or at most meso-level, determinants of vaccination coverage. There is a much smaller literature considering system-level factors influencing vaccination delivery, much of which is technical and tends to describe “ideal-type” systems (82,83,398,399), or addresses particular system functions such as monitoring (400). Most evidence comes from high income settings (401) or stable LMICs (398) rather than crisis settings. The bias towards individual behaviour is repeated in the research literature considering intervention strategies to improve coverage, which also focus on encouraging uptake at individual- or household-level (363).

The literature from humanitarian settings is particularly small, with just a handful of studies addressing approaches in these settings (63,81). Most existing work focuses on considerations such as modes of engagement with communities, and flexible dosing schedules in areas where access is challenging (47,51,64,86) rather than system characteristics, and is largely silent on key questions including the relationship between national immunisation systems and vaccination delivery under humanitarian response mechanisms. Recent technical guidance from the WHO on decision-making and programme implementation in crisis settings marks an important departure in emphasising system-level

considerations in vaccination delivery but is focused on the acute phase of crises (82,83). These deficits inform the selection of questions for the systematic review proposed as part of this research project (see the protocol in [Appendix 10](#)).

A2.3.1.3 Conclusion: problem identification

On the basis of material presented above, an initial problem conceptualisation was that ***there is a lack of understanding of how and why vaccination delivery systems respond to disturbances such as population movement in the ways that they do.***

A2.3.2 Step 2: mixed-methods country case study

This section presents a narrative overview of the operating context in Lebanon, and dynamics of vaccination delivery, based on a synthesis of peer- and non-peer-reviewed literature sources, exploratory discussions with system stakeholders and analysis of secondary data.

A2.3.2.1 Routine vaccination in Lebanon

A2.3.2.1.1 Operating context

Lebanon is a small country in the Middle East covering around 10,500 km², and with an estimated population of just over 6 million – although this figure is contested (200). Although political sensitivities mean that data from Lebanon are fragmented (199,402), it is clear that the demographic picture is changing rapidly. The Syria Crisis is the proximate cause of the latest in a long series of large-scale population displacements into Lebanon and within its borders, with around 920,000 registered Syrian refugees residing in the country as of November 2019 (alone constituting at least a quarter of the population) and a sizeable additional, unregistered refugee population (207). The proximate “shock” occurred from early 2013, when refugee arrivals in Lebanon from Syria rose rapidly and although cross-border movement in both directions continues, a large number of Syrians continue to reside in Lebanon (figure 6). The country also has a registered population of some 469,600 Palestinian refugees to whom health services are provided by UNRWA (208).

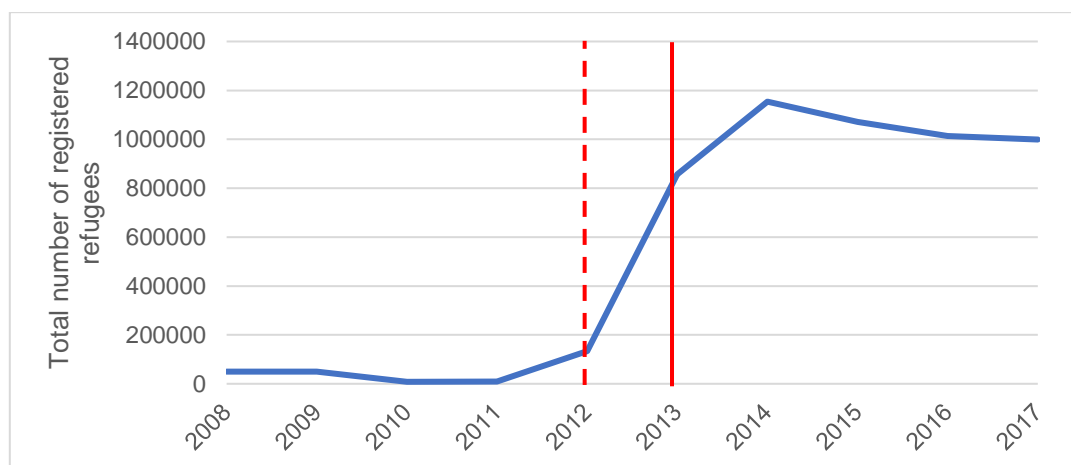


Figure 34. Ten-year trend in the total number of refugees registered by UNHCR in Lebanon since 2008. The vertical red-line indicates the point at which cross-border movement from Syria escalated rapidly – corresponding to the system shock of interest in this study. The beginning of the conflict in Syria is indicated by the dashed vertical line. UNHCR has been prevented from registering any new entrants from Syria by the Lebanese government since May 2015. Source: (403).

Although Lebanon operated a *de facto* open-border policy towards Syrian refugees between 2011 and 2014, the government's positioning vis-à-vis the crisis has been complicated by concerns over potentially destabilising spill over effects from the conflict there, embodied in the Dissociation Policy²⁷ introduced in 2012 (210,211). Since 2015, there has been a hardening of political rhetoric towards Syrian refugees, and in May of that year the government formally requested that UNHCR stop registering new arrivals from Syria (212). Relations between the government and many of the major agencies involved in the response are testy (213). The million or more displaced Syrians currently living in the country are scattered across 2,100 formal and informal settlements, many of them in governorates bordering Syria where public service access and quality for host communities have historically been poor. Some 76% of the displaced Syrian population in Lebanon live below the poverty line (203).

A2.3.2.1.2 Vaccination delivery, uptake and population coverage trends

The health sector in Lebanon is fragmented with a large private sector and complex relationships between “mainstream” health services and humanitarian response actors (223–227). Although some contemporary accounts emphasise the resilience of the health system in the face of large-scale population movements since the start of the Syria crisis (54), ground-level reality especially since 2013 (when cross-border movement escalated significantly) has been one of rapidly increasing demand and strain on health services, policymaking and implementation processes (203,231–233).

Vaccination access points in Lebanon vary by population²⁸. The Ministry of Public Health (MoPH) administers a nationwide EPI vaccination system for all those living in Lebanon, delivered through dispensaries and primary health centres (PHCs) and theoretically available to all (including refugees) for a nominal fee (234). A proportion of dispensaries and PHCs receive in-kind support from the MoPH but are operated and funded by third parties – principally not-for-profit providers. Other delivery mechanisms exist for displaced populations. Palestinian refugees are served by a network of clinics operated through the UN Relief and Works Agency (UNRWA). Syrian refugees can access routine vaccination at reduced cost through the EPI programme, the private sector and an emergent informal provider sector for

²⁷ This was intended to enforce neutrality by political actors in Lebanon towards the crisis but has had the effect of providing cover for limited recognition of rights for Syrians, who have no meaningful prospects of integration in Lebanon, and for whom – as an article of official government policy – no refugee camps can be established.

²⁸ Exploratory stakeholder discussion 3.

those who are not registered²⁹. People living in Lebanon also frequently access vaccination (both routine and non-mandated) from private healthcare providers – for which no systematic, national-level data collection exists. Costs across these access points also vary. Vaccination delivery through the EPI system is heavily subsidised so that patients theoretically cover only administration fees (typically ranging from US\$5-10 per consultation for Lebanese residents, \$2-5 for Syrian refugees)³⁰. Private provider fees for vaccination range from US\$20-100 per consultation excluding vaccine product costs.

From a governance and financing perspective, public and not-for-profit facilities in the PHC network must report EPI vaccination delivery data to the MoPH, which regulates activities in the sector. Financing and product procurement for the EPI programme overall lies with the MoPH with support from UNICEF (since 2013), which also provides technical input to programme oversight (234). Private sector providers operate independently of this system, procuring through separate mechanisms and delivering both routine and off-schedule vaccinations. A central theme in stakeholder discussions was the parlous state of financing for vaccination through the national EPI programme in Lebanon. As a middle-income country, it has limited recourse to funding support from international organisations such as Gavi and the MoPH is heavily dependent on domestic funding sources – leading several stakeholders to question the long-term sustainability of the programme in the face of rising demand.

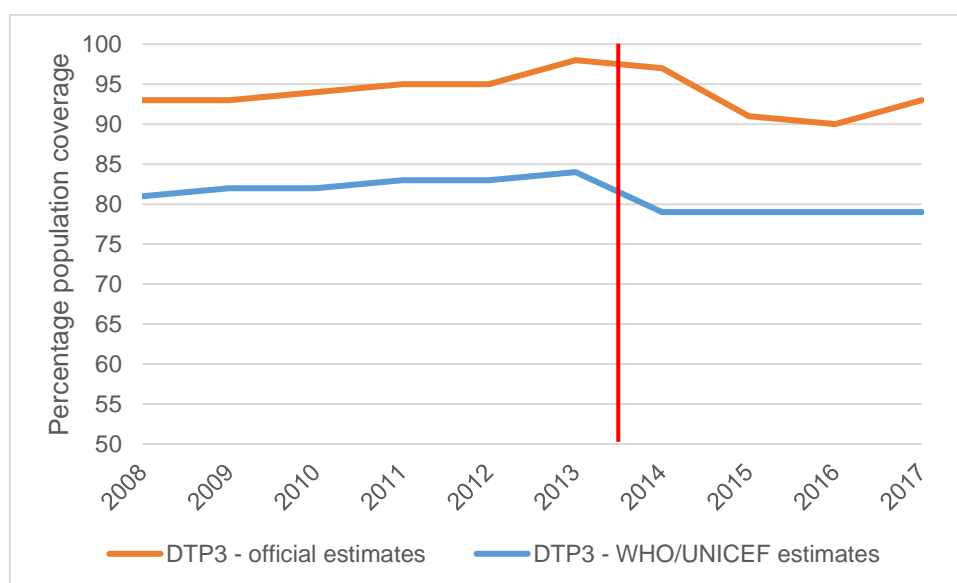


Figure 35. Ten-year trend in population-level DTP3 coverage in Lebanon from 2008 to 2017 from the Lebanese MoPH, and WHO/UNICEF.

The vertical red line indicates the “shock” point at which refugee arrivals escalated rapidly, and which – even in officially reported figures – manifests in a sharp decline in population DTP3 coverage.

²⁹ Ibid.

³⁰ Exploratory stakeholder discussions 2 and 3.

Building a clear picture of vaccination coverage and its determinants across populations in Lebanon is challenging because of data limitations (404). Coverage estimates derive from nationally reported figures (from MoPH and WHO/UNICEF – for which trends are discrepant, see figure 7) and periodic, cross-sectional population coverage surveys, most recently in 2016 (239). Nationally-reported coverage rates for both DTP3 and MCV1 (first dose measles vaccination) showed marked declines from 2013 onwards – the point at which refugee movement into Lebanon from Syria accelerated steeply. We also know that there are substantial variations in coverage across segments of the population and according to geographical location. The most recent EPI survey for Lebanon showed that DTP3 coverage rates among children in the Lebanese host population varied from 56.3% in the northern district of Bcharré (32% of children in this district had received no DTP doses at all at age 59 months) through to 95.1% in West Bekaa in the centre of the country. Overall coverage among Syrian refugees sampled in the survey (across Bekaa and Northern governorates) was 81.3% (239). Results from various geographically localised, cross-sectional analyses tend to show lower coverage rates among Syrian refugees than the Lebanese population on average (238,240,405).

These figures highlight limitations to the health system response to rising demand since 2013. While steps have been taken to strengthen cold-chain management nationwide³¹, stakeholder discussions suggest that there have been significant distorting effects on vaccination demand as a result of population movement, with reductions in particular from Lebanese residents through the EPI system in preference for private providers (partly as a result of declining trust in the quality of services at EPI providers, but also because of perceived competition from refugees)³², and continuing access barriers related to affordability for refugees (203,223,404). In addition, significant measles outbreaks in 2013, and again from 2018 onwards indicate endemic infection (406,407) and suggest that coverage for critical vaccinations among key segments of the population are sub-optimal.

A2.3.2.2 Routine vaccination in Uganda

A2.3.2.2.1 Operating context

Uganda is a large, sub-Saharan African country covering some 240,000km², and with a total population of 42.7 million in 2018 (200). As in Lebanon, the refugee population in Uganda is sizeable (an estimated 1,347,000 refugees in total as of November 2019 – around 3% of the population), but rather than large-scale, predominantly unidirectional population movement, the country has instead seen movement in multiple directions resulting from a series of concurrent humanitarian crises on its borders – notably in South Sudan to the north, and the

³¹ Stakeholder discussion 2.

³² Stakeholder discussions 1 and 2.

Democratic Republic of Congo (DRC) in the west – alongside internal factors. The main, proximate driver for movement was the outbreak of conflict in South Sudan in 2013, as a result of which over a million refugees have moved into the country (as of June 2019), but there has been a new influx since October 2018 from DRC (figure 8). Cross-border movement from DRC is active and currently increasing, with around 140,000 new arrivals since October 2018 (408). Refugees are distributed across the country but with particularly large populations in the north of the country, especially Yumbe and Adjumani districts in the far north (408).

As in Lebanon, Uganda hosts a number of refugee camps but has, as an article of official policy, moved away from encampment towards a degree of integration – at least in terms of access to services – with host communities. However, most refugees continue to live in settlements and the practical level of service integration and labour market opportunities open to them are variable across the country and over time (409). The Ugandan government has recently introduced an integrated health sector response plan which addresses aspects of health service delivery for refugees – including vaccination – through access to public sector health facilities (410).

A2.3.2.2.2 Vaccination delivery, uptake and population coverage trends

Routine vaccination in Uganda is administered through the national EPI programme (UNEPI) at the Ministry of Health (MoH), with technical input from the Ugandan National Immunization Technical Advisory Group (UNITAG). Nationally, UNEPI covers conventional governance functions including norm-setting, quality assurance, monitoring and evaluation and procurement (for the EPI vaccines for the routine schedule) (411). UNITAG's function centres on evaluation of clinical and health economic evidence on vaccine products to inform changes to the routine schedule (412). Responsibility for management and delivery of immunisation services lies with district, sub-district and facility-level actors – and the key local coordinating role is performed by the District Health Officer (DHO) in each of Uganda's 127 administrative districts, who oversees implementation and evaluation of immunisation-related activities across the public, private and third sectors. Districts typically also have a cold chain officer to ensure that vaccine stocks are appropriately maintained (411).

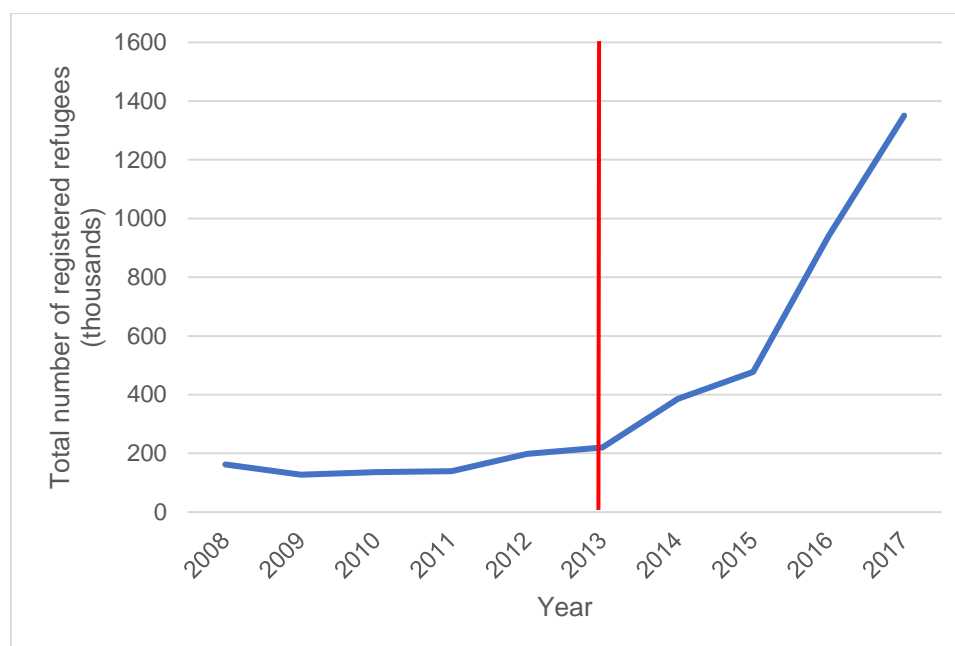


Figure 36. Ten-year trend in the total number of refugees registered by UNHCR in Uganda since 2008.

The vertical red line represents the proximate “shock” – the outbreak of conflict in neighbouring South Sudan which was the prompt for the latest surge in cross-border movement into Uganda. Source: (403).

Funding, product procurement and technical support for vaccination delivery is provided by the Ugandan government, with independent pathways for private providers. The Ugandan MoH is heavily reliant on donor support for vaccination financing. This includes substantial support from Gavi, the vaccine alliance, which has disbursed some \$407 million since 2000 for activities spanning cold chain optimisation, health system strengthening, and delivery of both routine vaccination and catch-up campaigns (pentavalent vaccination for some years, and measles in 2018, for example) (413). Gavi also supports delivery of selected non-mandated vaccinations (pneumococcal and HPV vaccines for example). UNICEF provides major financial and technical contributions to vaccination delivery for refugee and host community populations in Uganda, although it is difficult to disaggregate funding specifically covering vaccination from general health-related expenditure (414). UNHCR is also a key financial and technical supporter for primary healthcare delivery (including immunisation) through public or NGO intermediaries in the West Nile districts that accommodate the majority of the refugee population in Uganda (415).

In contrast to the mixed picture in Lebanon, access to routine vaccination for both host communities and refugee populations is primarily through the national EPI program and – following the abolition of user fees at first-level health facilities in Uganda in 2001 – this is nominally free of charge (416). There is, however, evidence that informal costs or co-payments are in practice hindering access to primary care services including vaccination (417). While vaccination – both on- and off-schedule – is also available through private providers, in

practice these account for a very small proportion (3%) of all facilities providing immunisations nationwide – the vast majority (82%) are in the public sector. Provision of immunisations to refugee populations under the Ugandan Minimum Service Package is also a core commitment under the country’s Health Sector Integrated Refugee Response Plan, published earlier in 2019. This spans access to routine vaccinations such as DTP3, and both routine and catch-up delivery of vaccination for epidemic-prone infections such as measles (410).

Data in the public domain on vaccination coverage for Uganda show marked improvements in coverage of key vaccinations in the early to mid-2000s (figure 9), followed by stagnation thereafter, though there are important variations nationwide. System-level drivers for the observed levelling off in population vaccination coverage have been explored elsewhere (102) but without an explicit focus on the potential role of population displacement.

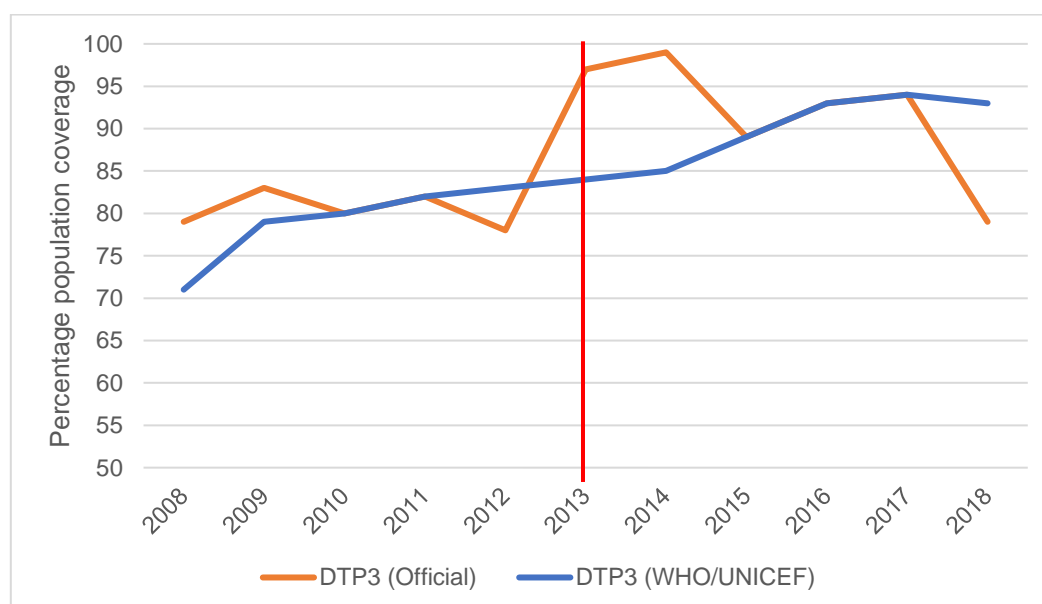


Figure 37. Trends in population-level DTP3 coverage in Uganda from 2008 to from the Ugandan MoH, and WHO/UNICEF.

The vertical red line indicates the “shock” point at which refugee arrivals from South Sudan escalated rapidly.

While national level coverage figures vary over time (see Figure 37), and no explicit association can be demonstrated here between population movement and aggregate vaccination coverage, there have been pronounced declines in officially-reported rates for almost all major vaccine products over 2017-18 as the number of refugees moving into the country has increased – including measles (from 97% in 2013 for MCV1 to 80% in 2018), DTP3 (97% to 79%) and inactivated polio vaccine (pol3 – 99% to 66%) (244). Detailed evidence on vaccination coverage among refugee populations by comparison with host communities from nationwide survey data suggests that rates are broadly comparable – albeit slightly lower among refugees on average (96.6% for measles among host communities, and 91.1% among refugees in a population-based survey carried out in 2017, for example) (418).

However, it should be noted that these data predate the large upswing in cross-border movement since 2016.

There is strong interest among policymakers in Uganda in means for addressing stagnating vaccination coverage – not least given a perception that UNEPI is one of the better-functioning health service delivery mechanisms in the country (418). Recent initiatives in this space have included the introduction of the Immunization Act in 2017, which theoretically mandates compulsory immunisation for children, women of reproductive age and “other target groups” (419) – although it remains unclear to what extent this law is implemented at local level.

A2.3.2.3 Conclusion

This section has outlined the scale and scope of population movements into Lebanon and Uganda in recent years, highlighting their dynamic and ongoing nature. It has describe the complex patterns of service delivery and access across populations that now exists in each country, and the contributory effect these factors have had on disruptions to routine vaccination delivery, and ultimately vaccination coverage. The working problem statement derived from this analysis is given in section A2.4.1.

A2.3.3 Step 3: synthesis

This section brings together findings from steps 1 and 2 to specify the methodological approach to be adopted for this research project. Rahmandad and Sterman present a useful framework for selecting the most appropriate complex systems modelling methodology depending on the characteristics of the system in question – between ABM and compartment-based approaches including SDM (192). The distinction between these two approaches hinges on whether the **characteristics of individual agents and their networks** or **system structures** are seen to be more important determinants of behaviour. “Agents” often refer in systems science to individuals but can also be actors such as organisations. While literature evidence and stakeholder testimony in the scoping study made clear that individual service user characteristics and perceived self-efficacy can be important determinants of demand, when considering vaccination *delivery*, interactions between elements of the system (for example in maintaining the cold chain, ensuring effective procurement or gathering and disseminating health intelligence) emerge as more important than the characteristics of agents themselves. This steers away from agent-based modelling as the most appropriate methodology. Further justification for the choice of modelling approach is given in section 1.4.3 in the main body of the thesis.

A2.4 Problem definition

A2.4.1 Problem statement

The working problem statement on the basis of findings outlined in the scoping study above is as follows:

Vaccination coverage may be disrupted over time in environments where there are large-scale population movements, with an attendant risk that the incidence and severity of vaccine-preventable diseases (VPDs) may increase. Maintaining threshold levels of population vaccination coverage under resource constraints in these contexts is a major policy and service delivery challenge for national vaccination programmes. We do not have a clear picture of either [1] the vaccination system characteristics or capacities that may explain how and why these systems adapt (or otherwise) to new service pressures when large-scale population movements takes place, or [2] intervention strategies that are likely to reinforce system ability to maintain or exceed threshold coverage rates.

A2.4.2 Reference modes

The reference mode assumes that, given an at least relatively well-functioning vaccination delivery system prior to the shock, population level vaccination coverage will steadily increase up to the point at which a major displacement occurs. At that point, we can expect a reduction in total population coverage, which – depending on the effectiveness of the system response – may or may not be transient.

Three stylised scenarios can be envisaged from this point forward (illustrated in the figure below):

- Optimal response: coverage recovers and continues on an upward trajectory towards a defined threshold.
- Sub-optimal response: coverage levels recover weakly and reach an equilibrium point below the threshold for herd immunity.
- Failure: population influx overloads the system and its adaptive or transformational capacity, so that population coverage falls so far below the threshold for herd immunity that population health protection cannot be guaranteed.

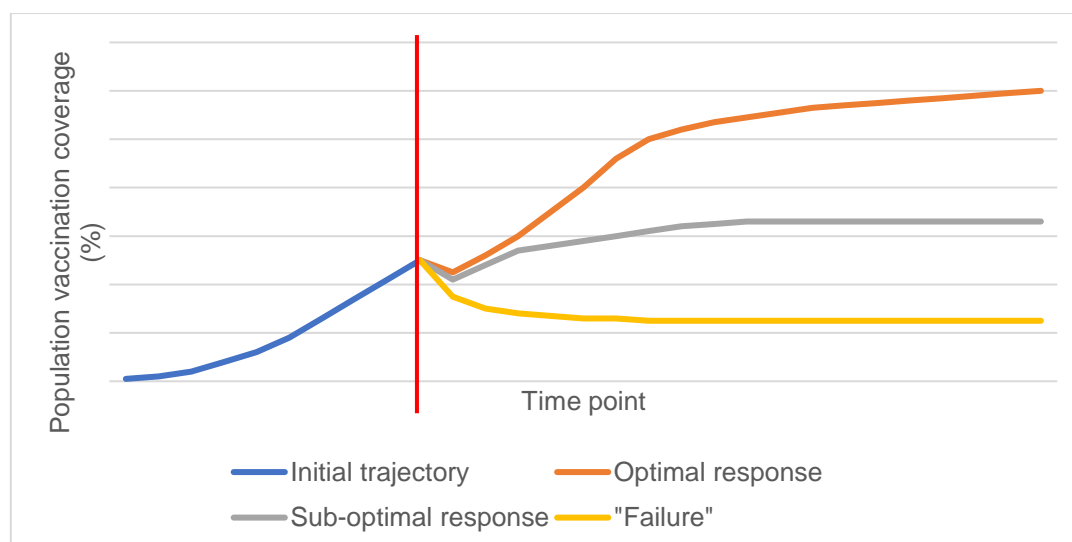


Figure 38. Reference mode and three putative trajectories for population vaccination coverage in each of the case study countries in the event of large-scale population movement

This figure assumes that the movement is cross-border (refugees) rather than internal displacement. The vertical red line represents the "shock" point – in this case a sudden population influx.

These reference modes will act as bases for discussions with stakeholders during primary data gathering, to try to understand how vaccination delivery systems in Lebanon and Uganda have actually responded to population movement.

Appendix 3: Timeline of key events

Contextual developments		Vaccination delivery system developments
National accreditation programme for PHCs launched	2009	
Beginning of Syria Crisis	2011	
Beginning of large-scale cross-border population movement March: inter-agency regional response plan to Syria Crisis initiated Registered refugee numbers increase from circa 12,000 in Feb/March to 156,000 by end December	2012	Implementing partner NGOs begin vaccine delivery to displaced populations through MMUs, in partnership with MoPH
Cases of AFP reported in Syria; polio vaccination campaign launched 804,848 registered refugees by 30/12/2013	2013	Nationwide measles and mumps outbreak reported National cluster survey for routine vaccination coverage carried out but does not include data on Syrians specifically
Dec: EU regional trust fund launched to support delivery of donor funds for projects in Lebanon and other countries, including for health 1,146,405 registered refugees by 31/12/2014	2014	April: MoPH issues circular requesting vaccination be administered free of charge at all PHCs May: MoPH issues circular promoting cooperation with private providers including through provision of vaccine doses procured through the Ministry Nationwide measles and mumps outbreak continues
Lebanese Government requests UNHCR stop registering new refugee arrivals in Lebanon 1,069,111 registered refugees by 31/12/2015	2015	Jan: LCRP launched – surge in donor commitments through the plan May: MoPH issues circular reinforcing shift from physician-administered to nurse-administered routine vaccination in PHCs (without consultation fees)
1,011,366 registered refugees by 31/12/2016	2016	National cluster survey for routine vaccination coverage carried, disaggregating Syrian and host community coverage rates for the first time

<p>Cases of AFP reported in Syria; polio vaccination campaign launched</p> <p>June: Lebanon Health Resilience Project (World Bank) launched, with module focusing on primary care service strengthening</p> <p>997,552 registered refugees by 31/12/2017</p>	2017	<p>Donor policy shift from funding staff and overhead costs to prioritising programmes; funding for MoPH staff reduced</p> <p>Revised National Immunisation Strategy and EPI multi-year plan of action issued</p>
<p>948,849 registered refugees by 31/12/2018</p>	2018	<p>Nationwide measles outbreak reported</p> <p>PHENICs e-record system launched</p> <p>Policy shift away from use of MMUs towards promotion of vaccination uptake for all populations through PHCs and other fixed sites</p>
<p>October: protest movement begins; Lebanese currency begins slide in value against US dollar</p> <p>914,648 registered refugees by 31/12/2019</p>	2019	<p>National measles vaccination campaign launched with donor support</p> <p>Mobile Epi Registry Application (MERA) e-record system launched</p>
<p>February: first COVID-19 cases reported in Lebanon</p> <p>March-May: first COVID-19 lockdown</p> <p>August: second COVID-19 lockdown; Beirut blast</p> <p>865,531 registered refugees by 31/12/2020</p>	2020	<p>MoPH launches programme to contract private clinics to deliver routine vaccinations free of charge, in exchange for vaccine dose supplies</p> <p>Large decline in reported vaccination uptake through PHCs</p> <p>National vaccination storage facility transferred from Karantina to Rafiq Hariri University Hospital in Beirut to preserve cold chain following Beirut blast</p>
<p>November: government subsidies on the costs of regular medications lifted</p> <p>840,929 registered refugees by 31/12/2021</p>	2021	
<p>825,081 registered refugees by 30/09/2022</p>	2022	<p>Expanded use of MMUs to meet local population demand for vaccination</p>

Appendix 4: Introduction to causal loop diagrams

Causal loop diagrams (CLDs) show cause and effect relationships between variables in a system. In a CLD, variables are linked by arrows which indicate both the direction of perceived effects, and – through the polarity (as indicated by a '+' or '-' sign) – the nature of the relationship. A positive polarity indicates a reinforcing relationship between variables so that as one increases, the linked variable does in turn. A negative polarity indicates an opposing effect, so that a rise in the value of the starting variable leads to a reduction in the resultant variable.

The use of hashed lines across an arrow linking two variables indicates a delay in movement from one to the next. These delays can broadly be of two types: (i) *information delays*, which describe the time taken to assemble and interpret relevant information that enables a system change to be perceived or acted upon; and (ii) *material delays*, which describe the time taken for movement of materials affecting downstream system behaviours. Supply chain and logistics problems are good examples of material delays; in the case of vaccination delivery, one might consider the delay between disbursement of vaccine doses from a central storage facility to their arrival at a health service provider for administration, and the range of potential factors contributing to this.

Figure 39 provides a simple illustration, showing the link between two variables used in this project: *PHC crowding*, and *Perceived ability to socially distance in PHCs*. In this example, as PHCs become more crowded, service users' confidence in being able to socially distance properly within those facilities reduces. There is also an information delay, in that it takes time for service users to become aware that local health facilities are crowded (unless they happen to be present in person).



Figure 39. Illustration of a negative polarity relationship between two variables using standard CLD notation.

This visualisation shows the link between primary healthcare facility crowding and service user-perceived ability to socially distance in those facilities (in the context of COVID-19 spread).

For more complex behaviours, variables may be linked together to form loops, in which feedback behaviour occurs. These can be *reinforcing* or *balancing*. In a reinforcing loop, a series of variables may be linked together by positive polarities, so that a positive feedback loop is created. These kinds of loops can lead to rapid growth or decline in the variables of interest over time. A balancing loop, by contrast, tends towards equilibrium, and is seen when the relationships between variables within a loop even each other out. Further detail on the

interpretation of CLDs can be found in a number of sources including Tomoia-Cotisel *et al* (117), or for those with time and interest to pursue more detail, in Sterman (113) or Morecroft (115).

Figure 40 provides an illustrative example of a balancing feedback loop, based on the stem given in Figure 39. In this example, an increase in the perceived ability to socially distance in health facilities, reduces the perceived risk of contracting COVID-19, in turn promoting attendance at those facilities, with a resulting increase in vaccination uptake. However, there is a feedback effect because as attendance rises, so too does PHC crowding, which tends to reduce perceived ability to socially distance, ultimately discouraging further PHC attendance.

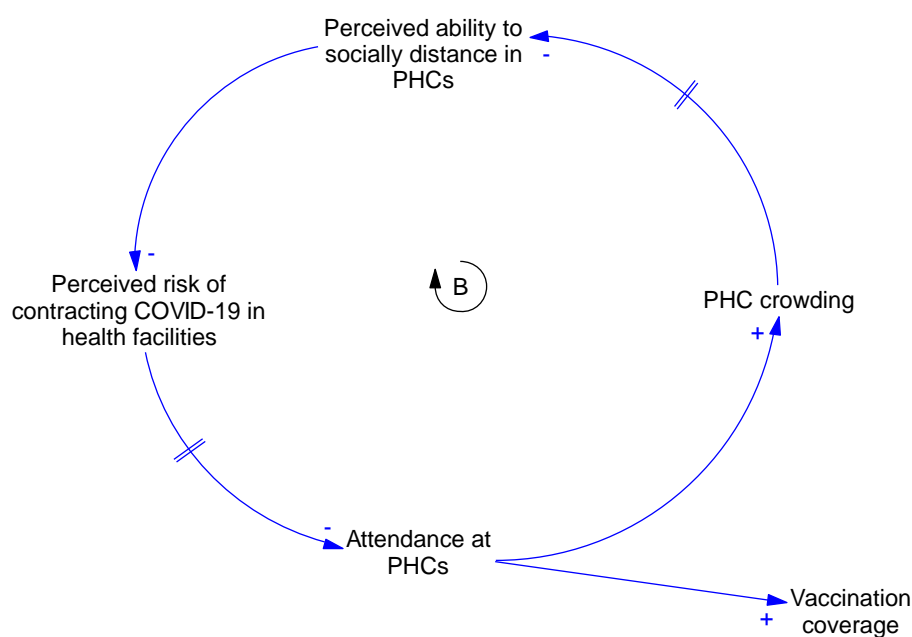


Figure 40. Example of a balancing feedback loop.

Appendix 5: Research tools used to support data collection through interviews

A5.1 Consent form

Title of Project: Strengthening national vaccination delivery systems for displaced populations in protracted crises

Name of Principal Investigator/Researcher responsible for project: Dr Fouad Fouad
(AUB)

Name of Co-Investigator: Dr Sharif Ismail
(LSHTM)

Statement	Please initial or thumbprint* each box
<p>I confirm that I have read the information sheet dated September 2020 (v4) for the above-named study. I have had the opportunity to consider the information, ask questions and have these answered satisfactorily.</p> <p><u>OR</u></p> <p>I have had the information explained to me by study personnel in a language that I understand. I have had the opportunity to consider the information, ask questions and have these answered satisfactorily.</p>	
<p>I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason, without my legal rights being affected.</p>	
<p>I understand that data about/from me/the participant may be shared via a public data repository or by sharing directly with other researchers, and that I will not be identifiable from this information</p>	
<p>I agree to take part in the above-named study</p>	

Printed name of participant	Signature of participant	Date

--	--	--

Printed name of impartial witness*

Signature of impartial witness*

Date

I attest that I have explained the study information contained in the information sheet dated September 2020 (v4) for the above study accurately, and that this was understood to the best of my knowledge by the participant, and that he/she has freely given their consent to participate* in the presence of the above named impartial witness (where applicable).

--	--	--

Printed name of person obtaining consent

Signature of person obtaining consent

Date

[*Only required if the participant is unable to read or write.]

Note to study participants: if your interview is taking place in person, Dr Ismail will ask you to sign a copy of this form at the time of the interview. If it is taking place remotely, please complete and sign this form as outlined above, and send it to Dr Ismail directly at:

sharif.ismail@lshtm.ac.uk.

A5.2 Semi-structured interview topic guides

A5.2.1 Topic guide for policymakers

INTERVIEW SCHEDULE FOR POLICYMAKERS

TITLE: Strengthening national vaccination delivery systems for displaced populations in protracted crises

PREAMBLE

Thank you for agreeing to speak with me today.

I am a researcher from the London School of Hygiene and Tropical Medicine in the UK and am conducting research in Lebanon with colleagues from American University of Beirut to understand how childhood vaccinations are delivered to different populations, and how we can help increase the number of people who have access to, and take up, those vaccinations in humanitarian settings. I am particularly interested in finding out more about how vaccination delivery from national to local in Lebanon works for host communities and for refugees, and

in understanding how recent challenges that Lebanon has been experiencing – including COVID-19 – have influenced this.

As outlined in the information sheet for this study, any information that you share in this discussion will be treated in confidence and will be fully anonymised for any onward publication arising from this work.

INTRODUCTORY QUESTIONS

1. Please outline your current role and explain your key responsibilities.
2. Please explain the role(s) your organisation plays in vaccination delivery in Lebanon.
 - a. PROBE: Delivery for host communities vs refugee populations
3. Please explain what the term “resilience” means to you.
 - a. PROBE: Do you think it is a meaningful to talk about system resilience in Lebanon at the moment? If not, how/where should attention be focused instead?
 - b. PROBE: What factors do you think influence the resilience of the vaccination delivery system, and why?

DYNAMIC RESPONSES OF THE SYSTEM (likely that most interviewees will discuss, interchangeably, the effects of population displacement, economic crisis and COVID-19 – questions as ordered are for guidance only):

4. What effect (if any) has population displacement had on immunization delivery in Lebanon?
 - a. PROBE: for each listed effect – why did it occur?
 - b. PROBE: effects on the caseload of vaccine-preventable disease (VPDs)
 - c. PROBE: How has the national program/system responded to new demands placed on it?
 - i. PROBE: Where there aspects or parts of the program that performed well? Why?
 - ii. PROBE: Where there aspects or part of the program that did not perform well? Why?
 - iii. PROBE: Where there differences in how the program responded to meet the needs of different populations, or different parts of the country? Why?

iv. PROBE: If outbreaks of VPDs have occurred across these populations, can you describe the nature of the response? Why did the response pan out in this way?

In this next part, I'd like to turn to some of the more recent events in Lebanon and their effect(s) on vaccination delivery.

5. What impact have economic difficulties since October 2019 had on vaccination delivery if any? Why?
 - a. PROBE: Human resourcing issues, supply chains, access to foreign currency; others
 - b. PROBE: Effects on service demand – have any changes been noted, and if so what/how? Have particular populations been affected?
 - c. PROBE [trade-offs]: How have these pressures influenced what you do (if at all)? Have you had to change the way(s) you work, and if so how?

6. What impact has COVID-19 had on childhood vaccination delivery, and how has your organisation/the system responded to this?
 - a. PROBE: What effect, if any, has COVID-19 had on demand for routine immunisations?
 - b. PROBE: Did you have to make any changes to the way you work to allocate resources to COVID-19 and if so how?
 - c. PROBE: What effect(s), if any, did this have on delivery of/your work on routine immunisations? Why/how?
 - d. PROBE: Are you/is your organisation involved in COVID-19 vaccination delivery? If so, how?
 - i. Have there been any knock-on effects for routine immunisation in allocation of resources/effort to COVID-19 vaccination delivery? If so, how/why?
 - ii. Has it been possible to leverage your work on routine immunisation to support COVID-19 vaccination delivery? If so, how?

METRICS (if not already picked up in earlier sections)

7. What do you think are the most important measures of success in vaccination delivery, and why?
 - a. PROBE: ask about specific metrics that the interviewee uses or is aware of, or that they use in their role
 - b. PROBE: data sources – routine and otherwise – for these metrics

WRAP-UP

8. Is there anything else that you would like to raise with me today?
9. Is there anyone else you would recommend that I speak to about this?

Thank you for taking the time to speak with me today.

A5.2.2 Topic guide for service managers

INTERVIEW SCHEDULE FOR SERVICE MANAGERS

TITLE: Strengthening national vaccination delivery systems for displaced populations in protracted crises

PREAMBLE

Thank you for agreeing to speak with me today.

I am a researcher from the London School of Hygiene and Tropical Medicine in the UK and am conducting research in Lebanon with colleagues from American University of Beirut to understand how childhood vaccinations are delivered to different populations, and how we can help increase the number of people who have access to, and take up, those vaccinations. I am particularly interested in finding out more about how vaccination delivery from national to local in Lebanon works for host communities and for refugees. I would like to hear more about your perspective on vaccination service delivery, and how recent challenges that Lebanon has been experiencing – including COVID-19 – have influenced this.

As outlined in the information sheet for this study, any information that you share in this discussion will be treated in confidence and will be fully anonymised for any onward publication arising from this work.

INTRODUCTORY QUESTIONS

10. Please outline your current role and explain your key responsibilities.
11. Please tell me about the clinic/service that you manage.
- PROBE: What population(s) do you serve? How many people attend your service/clinic in a day/week/year? How many vaccinations do you administer in a day/week/year?
 - PROBE: How many health workers are employed by your service/clinic? How many are directly involved in vaccination deliver?
12. What does the term “resilience” mean to you?
- PROBE: Do you think it is meaningful to talk about system resilience in Lebanon today?

THE STRUCTURE OF THE SYSTEM

13. Please describe how routine vaccinations are delivered in [AREA/DISTRICT]?
- PROBE: What are the key components of service delivery for vaccination locally?
 - FURTHER PROBE: who do you report to concerning the performance of your service/clinic on vaccination, and how?
 - PROBE: What are the costs of vaccination delivery for your service?
 - PROBE: do processes and costs differ in significant ways between host communities, refugees and those who are internally displaced? How/why?
 - PROBE: What role (if any) does outreach play in service delivery in your area?
 - ANCHORING PROBE: have any of the details you outline changed significantly since [DATE OF SHOCK]? If so, what was different then?**

DYNAMIC RESPONSES OF THE SYSTEM

14. What effect (if any) has population movement had on your ability to deliver vaccination locally?
- PROBE: demand-side and supply-side factors
 - PROBE: for each listed effect – why did it occur?
 - PROBE: perceived effects on the caseload of vaccine-preventable disease (VPD)
15. How has your service responded to demand from different population groups locally since [DATE OF SHOCK]?
- PROBE: Where there aspects or parts of the service that performed well? Why?

- b. PROBE: Where there aspects or part of the service that did not perform well? Why?
- c. PROBE: Have there been stock-outs (vaccine products or ancillary products needed to deliver them)? If so, why? And how have staff responded to these?
- d. PROBE: Where there differences in how the service was able to respond to meet the needs of different populations or geographical locations? Why?
- e. PROBE: If outbreaks of VPDs have occurred, can you describe how your service/clinic has responded?

16. What impact have economic difficulties since October 2019 had on vaccination delivery locally?

- a. PROBE – demand: effects on service usage/uptake
- b. PROBE – supply: effects on HR, supply chains, service demand
- c. PROBE: Have you had to work differently in delivering vaccinations to your beneficiaries, and if so how?

17. What impact has COVID-19 had on routine childhood vaccination delivery in your clinic/service, and how have you responded to this?

- a. PROBE – demand: effects on service usage/uptake
- b. PROBE: Did you have to make any changes to the way you deliver services to allocate resources to COVID-19 response and if so how?
- c. PROBE – trade-offs: What effect(s), if any, has this had on delivery of routine immunisations? How/why?
- d. PROBE: Are you/is your organisation involved in COVID-19 vaccination delivery? If so, what model(s) are you using to do this?

METRICS (if not covered elsewhere)

18. What do you think are the most important measures of success in vaccination delivery, and why?

- a. PROBE: ask about specific metrics that the interviewee uses in their work or is aware of
- b. PROBE: data sources – routine and otherwise – for these metrics

WRAP-UP

19. Is there anything else that you would like to raise with me today?

20. Is there anyone else you would recommend that I speak to about this?

Thank you for taking the time to speak with me today.

A5.2.3 Topic guide for healthcare workers

INTERVIEW SCHEDULE FOR HEALTHCARE WORKERS

TITLE: Strengthening national vaccination delivery systems for displaced populations in protracted crises

PREAMBLE

Thank you for agreeing to speak with me today.

I am a researcher from the London School of Hygiene and Tropical Medicine in the UK and am conducting research in Lebanon with colleagues from American University of Beirut to understand how childhood vaccinations are delivered to different populations, and how we can help increase the number of people who have access to, and take up, those vaccinations. I am particularly interested in finding out more about how vaccination delivery from national to local in Lebanon works for host communities and for refugees. As a healthcare worker delivering vaccinations in your day-to-day work I would like to hear more about your work and factors that make it easier or harder to do your job.

As outlined in the information sheet for this study, any information that you share in this discussion will be treated in confidence and will be fully anonymised for any onward publication arising from this work.

INTRODUCTORY QUESTIONS

21. Can you please outline your current role and explain your key responsibilities?

- a. PROBE: How did you come to occupy your current position?
- b. PROBE: What role do you have in administering or providing vaccinations?

22. Can you please tell me about the service/clinic in which you work?

- a. PROBE: How many health workers, besides yourself, are involved in giving vaccinations?
- b. PROBE: How many patients do you see in a day/week for vaccination administration and who are they?

THE STRUCTURE OF THE SYSTEM

23. Can you describe how, in your view, routine vaccinations are delivered in your clinic/centre?
- a. PROBE: Can you describe the process of delivery in your clinic/centre?
 - b. PROBE: What are the costs of vaccination delivery for your clinic/centre?
 - c. PROBE: Do the processes and costs you have outlined above differ between patient groups (host communities, refugees, those who are internally displaced)?
 - d. **ANCHORING PROBE: have any of the details you outline changed significantly since [DATE OF SHOCK]? If so, what was different then?**
24. What do you think are the most important measures of success in vaccination delivery, and why?
- a. PROBE: ask about specific metrics that the interviewee uses in their work or is aware of
 - b. PROBE: data sources – routine and otherwise – for these metrics
25. What factors do you think determine the ability of your clinic/centre to provide vaccinations for people living in [AREA/DISTRICT], and why?
- a. PROBE: around the WHO health system building blocks as above
 - b. PROBE: supply-side factors e.g. procurement, supply chain management, cold chain management etc
 - c. PROBE: demand-side factors e.g. population size, patient perceptions etc
 - d. PROBE: do these differ in meaningful ways for different vaccine-preventable diseases?
 - e. PROBE: do these factors, or the balance between them, differ according to the target population(s) identified above?
 - f. **ANCHORING PROBE: have any of the details you outline changed significantly since [DATE OF SHOCK]? If so, what was different then?**

DYNAMIC RESPONSES OF THE SYSTEM

26. What effect (if any) has population movement had on your ability to deliver vaccination locally?
- PROBE: what proportion of the patients that you see do you think are refugees/members of host communities?
 - PROBE: demand-side and supply-side factors?
 - PROBE: for each listed effect – why?
27. How has your service responded to the challenges identified above, and why?
- PROBE: Where there aspects or parts of clinic/centre's work that performed well? Why?
 - PROBE: Where there aspects or part of the clinic/centre's work that did not perform well? Why?
 - PROBE: have there been stock-outs (vaccine products or ancillary products needed to deliver them)? If so, how have staff responded to these?
 - PROBE: Where there differences in how the clinic/centre was able to respond to meet the needs of different populations or geographical locations? Why?
 - ANCHORING PROBE: have any of the details you outline changed significantly since [DATE OF SHOCK]? If so, what was different then?**
28. What are the key challenges that your clinic/centre has faced recently in delivering vaccinations [OR SPECIFY DURATION DEPENDING ON LENGTH OF TIME IN POST], and why?
- PROBE: background and nature of the challenges identified – using the WHO health system building blocks if necessary
 - PROBE: nature and duration of effect(s)
 - PROBE: geographical location/spread of impact

WRAP-UP

29. Is there anything else that you would like to raise with me today?
30. Is there anyone else you would recommend that I speak to about this?

Thank you for taking the time to speak with me today.

Appendix 6: RIQ template for purposive text analysis

As outlined in Chapter 4, the qualitative system dynamics component of this thesis employed purposive text analysis as those chosen approach to analysis of interview data. Full details of the method as given in Chapter 4. Here, the template for interpretation of quotes is provided, along with a sample quote interpretation.

Participant quotation:	<u>“Nevertheless, some mumps, measles outbreaks took place, sometimes it was because of the [refugee] influx, but also sometimes because it was low coverage in some specific areas in Lebanon.”</u>
Analysis	
<i>Quote segment</i>	<i>Variable identified</i>
“Nevertheless, some mumps, measles outbreaks took place”	VPD outbreaks
“Sometimes it was because of the [refugee] influx”	Refugee arrivals
“Sometimes because it was low coverage”	Vaccination coverage
“low coverage in some specific areas in Lebanon”	Cadasters with low vaccination coverage
Interpretation	
<i>Causal structure</i>	<i>Explanatory text from the quote</i>
<i>Refugee arrivals -->+VPD outbreaks in Lebanon</i>	Some outbreaks took place...sometimes because of the influx
<i>Vaccination coverage-->-VPD outbreaks in Lebanon</i>	Some outbreaks took place...sometimes because it was low coverage
<i>Cadasters with low vaccination coverage-->+VPD outbreaks in Lebanon</i>	Some outbreaks took place...sometimes because it was low coverage in some specific areas in Lebanon
Visual interpretation:	
<pre> graph LR RA[Refugee arrivals] -- "+" --> VPO[VPD outbreaks] VC[Vaccination coverage] -- "-" --> VPO CLVC[Cadasters with low vaccination coverage] -- "+" --> VPO </pre>	

Appendix 7: Tracking saturation through CLD combination and validation

In order to test the extent to which saturation had been reached in development of combined CLDs from different stakeholder groups, saturation plots were generated for both CLD combination, and subsequent validation of the final, aggregated CLD. These plots are intended to give a quantitative sense of the contribution of new manuscripts to elaborating the CLD, and measure, respectively, the number of new variables, links, delays and feedbacks introduced with each additional CLD. As CLD development proceeds to saturation, one would expect the number of new additions with each transcript to tend towards zero.

The plots overleaf for CLD combination give a visual indication of the extent to which saturation was reached across stakeholder groups. Clusters correspond to the stakeholder categories identified in section 4.3.2. The second set of figures visualises saturation in CLD validation using the validation set of interviews.

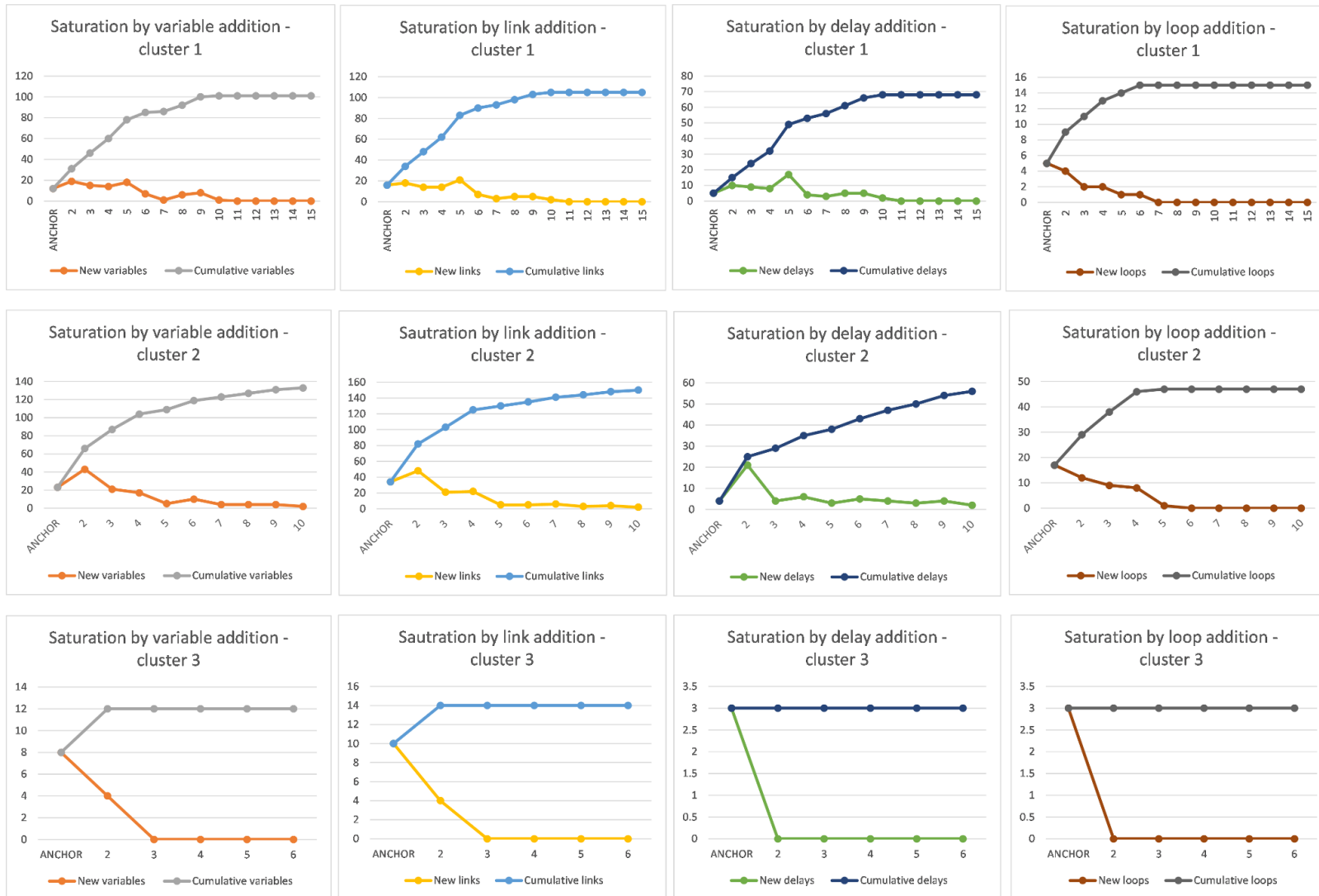


Figure 41. Saturation curves by variable addition, link addition, delay addition and feedback loop addition for each additional CLD added from the anchor CLD during the CLD combination phase.

Clusters correspond to the stakeholder category (where cluster 1 = national level stakeholders; cluster 2 = regional stakeholders and implementing partners; and cluster 3 = facility-level interviewees).

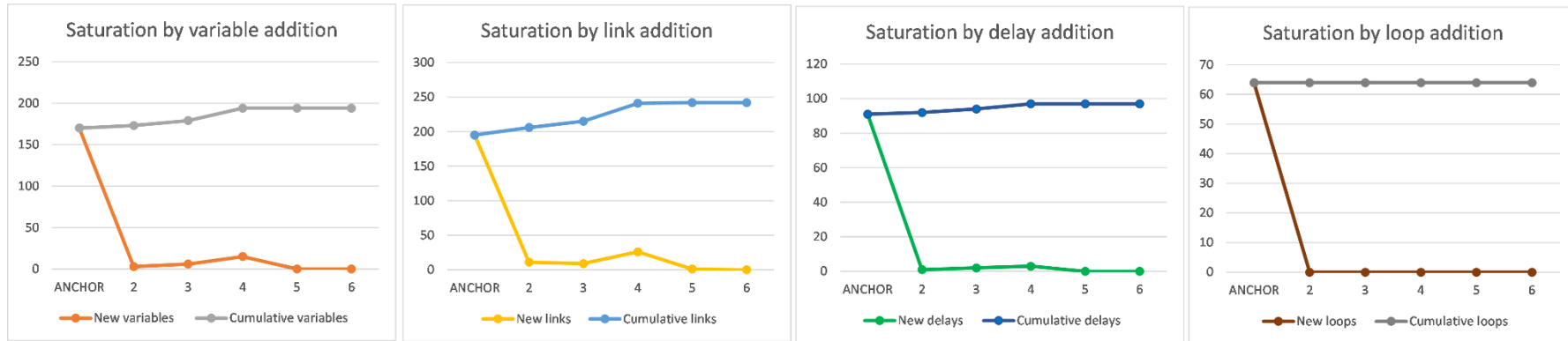


Figure 42. Saturation curves by variable addition, link addition, delay addition, and feedback loop addition, for each additional validation interview added beyond the anchor. In this case the anchor was the aggregated CLD from the initial CLD development step.

Appendix 8: Ethical approvals

A8.1 LSHTM approval - UK

London School of Hygiene & Tropical Medicine

Keppel Street, London WC1E 7HT
 United Kingdom
 Switchboard: +44 (0)20 7636 8636
www.lshtm.ac.uk



Observational / Interventions Research Ethics Committee

Dr Sharif Ismail
 LSHTM

11 December 2019

Dear Dr Sharif Ismail

Study Title: Strengthening national vaccination delivery systems for displaced populations in protracted crises: modelling delivery in the context of large-scale displacement in Lebanon and Uganda

LSHTM Ethics Ref: 17461

Thank you for responding to the Observational Committee's request for further information on the above research and submitting revised documentation.

The further information has been considered on behalf of the Committee by the Chair.

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 as revised, 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
Protocol / Proposal	Sharif Ismail_thesis research protocol_v0.01	26/08/2019	1.0
Investigator CV	Short CV international 2019_v0.02	27/08/2019	1.0
Protocol / Proposal	KII schedule_policymakers_v0.01	29/08/2019	1.0
Protocol / Proposal	KII schedule_HCWs_v0.01	29/08/2019	1.0
Protocol / Proposal	KII schedule_service managers_v0.01	29/08/2019	1.0
Protocol / Proposal	KII schedule_generalizability testing_v0.01	29/08/2019	1.0
Advertisements	Recruitment email template_policymakers_CLD_v0.01	30/08/2019	1.0
Advertisements	Recruitment email template_service managers_CLD_v0.01	30/08/2019	1.0
Advertisements	Recruitment email template_policymakers_generalizability test_v0.01	30/08/2019	1.0
Advertisements	Recruitment email template_service managers_generalizability test_v0.01	30/08/2019	1.0
Information Sheet	Template information sheet_managers and healthcare workers_generalizability test_v0.01	30/08/2019	1.0
Information Sheet	Template information sheet_policymakers_generalizability test_v0.01	30/08/2019	1.0
Information Sheet	Template information sheet_managers and healthcare workers_CLD_v0.01	30/08/2019	1.0

Information Sheet	Template information sheet_policymakers_CLD_v0.01	30/08/2019	1.0
Protocol / Proposal	Sharif Ismail_thesis research protocol_v0.02_TRACKED	02/12/2019	2.0
Covering Letter	Response Cover Letter_SHARIF ISMAIL_02.12.2019	02/12/2019	2.0
Other	NIHR Good Clinical Practice (GCP) certificate_SHARIF ISMAIL	02/12/2019	1.0
Other	NIHR Good Clinical Practice (GCP) Refresher eLearning_Good Clinical Practice Refresher Certificate_SHARIF ISMAIL	02/12/2019	1.0
Other	CITI certification_human subjects research_SHARIF ISMAIL	02/12/2019	1.0
Information Sheet	Informed consent template_v0.02	02/12/2019	2.0

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 Jimmy Whitworth
Chair

ethics@lshtm.ac.uk
<http://www.lshtm.ac.uk/ethics/>

Improving health worldwide

A8.2 AUB approval – Lebanon



Institutional Review Board | لجنة الأخلاقيات

www.aub.edu.lb

APPROVAL OF RESEARCH

February 4, 2020

Dr. Fouad M. Fouad
American University of Beirut
01-350000 Ext. 4654
mm157@aub.edu.lb

Dear Dr. Fouad,

On February 4, 2020, the IRB reviewed the following protocol:

Type of Review:	Initial, Expedited
Project Title:	Strengthening national vaccination delivery systems for displaced populations in protracted crises: modelling delivery in the context of large-scale displacement in Lebanon and Uganda
Investigator:	Fouad M. Fouad
IRB ID:	SBS-2019-0376
Funding Agency:	Wellcome Trust Clinical Research Training Fellowship (award no. 215654/Z/19/Z)
Documents reviewed:	Received September 20, December 30, 2019 & January 31, 2020: Response Letter, Amended IRB Application, Proposal, Interview Guide- Policymakers (Arabic and English versions), Interview Guide- Managers (Arabic and English versions), Interview Guide- Healthcare workers (Arabic and English versions), Amended Invitation Script- Policymakers (Arabic and English versions), Amended Invitation Script- Healthcare workers + Managers (Arabic and English versions), Amended Participant Information sheet + Consent- Policymakers (Arabic and English versions), Amended Participant Information sheet + Consent- Healthcare workers + Managers (Arabic and English versions).

The IRB approved the protocol from **February 4, 2020 to February 3, 2021** inclusive.

Before December 3, 2020 or within 30 days of study close, whichever is earlier, you are to submit a completed "FORM: Continuing Review Progress Report" to request continuing approval or study closure.



Institutional Review Board | لجنة الأخلاقيات

www.aub.edu.lb

If continuing review approval is not granted before the expiration date of **February 4, 2021**, approval of this research expires on that date.

Please find attached the stamped approved documents:

- Proposal (received September 20, 2019),
- Interview Guide- Policymakers Arabic and English versions (received September 20, 2019),
- Interview Guide- Managers Arabic and English versions (received September 20, 2019),
- Interview Guide- Healthcare workers Arabic and English versions (received September 20, 2019),
- Invitation Script- Policymakers Arabic and English versions (received January 31, 2020),
- Invitation Script- Healthcare workers + Managers Arabic and English versions (received January 31, 2020),
- Participant Information sheet + Consent- Policymakers Arabic and English versions (received January 31, 2020),
- Participant Information sheet + Consent- Healthcare workers + Managers Arabic and English versions (received January 31, 2020).

Only these IRB approved consent forms and documents can be used for this research study.

Thank you.

The American University of Beirut and its Institutional Review Board, under the Institution's Federal Wide Assurance with OHRP, comply with the Department of Health and Human Services (DHHS) Code of Federal Regulations for the Protection of Human Subjects ("The Common Rule") 45CFR46, subparts A, B, C, and D, with 21CFR56; and operate in a manner consistent with the Belmont report, FDA guidance, Good Clinical Practices under the ICH guidelines, and applicable national/local regulations.

Sincerely,

Michael Clinton, PhD
Co-Chairperson IRB Social & Behavioral Sciences

Cc:

Fuad Ziyadeh, MD, FACP, FRCP
Professor of Medicine and Biochemistry
Chairperson of the IRB

Ali K. Abu-Alfa, MD, FASN, FAHA
Professor of Medicine
Director, Human Research Protection Program
Director for Research Affairs (AUBMC)

Appendix 9: Systematic review – developing a working analytical framework

Understanding of which interventions may bolster system resilience in health, and how remains limited partly because of enduring analytical differences over the way in which resilience is conceptualised (9,12). There is, however, a degree of consensus in the health literature on the kinds of *attributes* associated with system resilience, if not necessarily the means by which these can be enhanced. They include “hard” attributes such as availability of material and human resources, and the existence of collateral pathways (i.e. the existence of multiple mechanisms through which, for example, medical products or health services can be delivered) (18,139). Effective information management is also vital although the balance between formal surveillance and softer, more immediate data from human intelligence systems in shaping system responses has emerged as an area of debate in humanitarian settings and in the context of COVID-19 responses (153,154). “Soft” attributes include features such as networking and connectivity (141). Empirical studies of resilience governance and system leadership have been few including in health, although existing health research does identify attributes including legitimacy and knowledge management as important (10,137,152). These attributes may derive in part from the health system and wider context in which interventions operate, but also form part of activities linked to the intervention itself.

While the ultimate goal of vaccination delivery systems can be considered to be generating improvements in vaccination coverage, and thereby population health outcomes (including mortality and morbidity from VPDs), the attributes described imply a focus on interventions that act through intermediate pathways, such as improvements in the quality of health information, integration with other services and service providers, the scale and durability of resource inputs (human, financial and others) and so on. These, and other similar outcomes, form an important focus for this review: our focus was not just on vaccination delivery endpoints (population coverage, deaths and hospitalisations averted, for example) but also on the system outputs and outcomes through which these effects were achieved.

We therefore developed a working framework to enable a layered reading of included articles, exposing:

- Context: including both the broader national context and humanitarian crisis within which the intervention implementation occurred, as well as the background state of the health system (understood with reference to the WHO health system building blocks)
- Mechanism: as a function of intervention activities on the health system building blocks, the ways in which these supported the development of recognised resilience attributes (such as collateral service pathways, strengthened networking and other features highlighted above) and ultimately the specific mechanism (whether absorptive, adaptive, or transformative) by which resilience was strengthened as a result of the intervention.
- Outcomes: vaccination-related outcomes as set out in the methods section, and as reported by included articles.

The framework outlines a loose progression from inputs to outcomes (e.g., increased vaccination coverage) but does not make explicit assertions about causal links between individual elements, about feedback loops that are, in reality, likely to apply, or about the dynamic nature of the relationship between interventions and wider context. This is because the nature of these relationships is likely to vary from intervention to intervention.

Appendix 10: Systematic review – protocol

This appendix provides the systematic review protocol as documented on PROSPERO.

Interventions for strengthening vaccination delivery systems in the context of protracted humanitarian crises: protocol for a realist-informed systematic review

Citation

Sharif Ismail, Walter Lam. Interventions for strengthening vaccination delivery systems in the context of protracted humanitarian crises: protocol for a realist-informed systematic review. PROSPERO 2021 CRD42021273124 Available from: https://www.crd.york.ac.uk/prospero/display_record.php?ID=CRD42021273124

Review question

The review will address the following research questions:

- What is known about the impact of system-level interventions on vaccination coverage in countries experiencing protracted humanitarian crises, when, where and for whom (considering host communities, refugees and internally displaced populations)?
- What promising, system-level interventions may be identified with early-stage evidence of impact on key vaccination delivery outcomes in these settings?
- What is known about how these interventions operate at system-level, with a view to tailoring them to local implementation?

Searches

Searches will span peer-reviewed journal databases including MEDLINE, the Cochrane Central Register of Controlled Trials (CENTRAL), Cumulative Index to Nursing and Allied Health Literature (CINAHL), EMBASE, Global Health and the WHO Library Information System (WHOLIS).

Searches will also be conducted across relevant portals for technical evidence and guidance (e.g. Technet-21) and websites of key global organisations including WHO, Global alliance for vaccine and immunisation (Gavi), and UNICEF among others to identify relevant peer-reviewed and grey literature.

Reference snowballing will be performed from studies identified through the above to find additional studies of potential relevance.

In broad terms, the review will include peer-reviewed journal articles, conference abstracts, agency and NGO evaluation reports, government reports and plans, presentations, WHO SAGE documents, guidelines and guidance documents. With respect to study designs:

- + For peer-reviewed papers, study designs may span systematic reviews and meta-analyses, randomised controlled trials, interrupted time series analyses, repeated cross-sectional studies (i.e. primary studies).
- + Grey literature sources will need to report original findings from population-based studies of the kinds identified above, or programme or policy evaluations. Formats may include formal reports, working papers, powerpoint presentations, etc.

A basic principle for inclusion is that studies will need to report data (qualitative, quantitative or mixed-methods in origin).

Types of study to be included

In broad terms, the review will include peer-reviewed journal articles, conference abstracts, agency and NGO evaluation reports, government reports and plans, presentations, WHO SAGE documents, guidelines and guidance documents. With respect to study designs:

- + For peer-reviewed papers, study designs may span systematic reviews and meta-analyses, randomised controlled trials, interrupted time series analyses, repeated cross-sectional studies (i.e. primary studies).
- + Grey literature sources will need to report original findings from population-based studies of the kinds identified above, or programme or policy evaluations. Formats may include formal reports, working papers, powerpoint presentations, etc.

A basic principle for inclusion is that studies will need to report data (qualitative, quantitative or mixed-methods in origin).

Condition or domain being studied

The focus of this review is on routine (EPI) immunisation delivery in low- and middle-income countries (LMICs) affected by protracted humanitarian crises.

Participants/population

Populations in LMICs affected by humanitarian crisis (but beyond the acute response phase) with a particular focus on children aged 0-5 as the focus of most routine vaccination programmes, but incorporating older displaced children, teenagers and adults in consideration of, for example, catch-up programmes.

Intervention(s), exposure(s)

System interventions at meso- or macro-level with explicit or potential effects on either or both of the primary and secondary outcome domains defined below. Interventions must operate at the relevant system level, defined as follows:

1. Meso-level:

- + Supply side: area-based (i.e. district, governorate or equivalent level and above), health sector interventions addressing system resilience directly, or alternatively specifying activities under one or more of the WHO's six health system building blocks; OR interventions targeting specific tranches of the vaccination delivery pathway e.g. cold-chain maintenance;
- + Demand side: meso-level interventions focused on refugee or otherwise displaced populations in crises with demonstrated effects on population health outcomes (e.g. cash transfer programmes), with the overall objective of increasing population demand for, and uptake of, vaccination

2. Macro-level: interventions addressing system resilience at national level directly, or alternatively concurrently addressing a number of the WHO's six health system building blocks at national level; OR interventions targeting specific tranches of the vaccination delivery pathway at national level.

Comparator(s)/control

This will vary according to the design of individual, included studies.

Context

LMICs (defined according to World Bank Country and Lending Groups classification) with large, within-year refugee movements or internally displacements documented (>10, 000 individuals). A target country list will be identified by mapping the following against one another:

1. Numbers of registered refugees, by year, for all LMICs in the period 2005-2020 drawing on publicly available UNHCR data;
2. Numbers of internally displaced persons, by year, for all LMICs in the period 2008-2020 drawing on publicly available data from the Internal Displacement Monitoring Centre (IDMC).

Main outcome(s)

Vaccination coverage for one or more of the antigens short-listed in the WHO's 2017 guidance document outlining decision-making approaches for vaccination delivery in acute humanitarian emergencies (<https://apps.who.int/iris/handle/10665/255575>).

Measures of effect

Coverage rate (administrative or survey-based) for specific antigens considered in included studies.

Additional outcome(s)

Secondary outcomes will be considered in two categories:

+ Vaccination delivery outcomes as defined by included studies but likely including rates and reported caseloads for vaccine-preventable diseases (VPDs); access to routine immunization (typically defined as the proportion of eligible children within a given time period in receipt of a particular antigen dose); drop-out rates (for multiple dose regimens); facility readiness metrics; and

+ Stated system resilience indicators e.g. the presence of systems for protecting financing for vaccination, available vaccine stock, workforce numbers and reserve etc (these are likely to vary from study to study because the resilience literature is nascent).

Measures of effect

These will vary according to the secondary outcome considered.

Data extraction (selection and coding)

Screening for inclusion will be performed sequentially on title/abstract and then full text. Screening will be performed in duplicate by two members of the study team, with discrepancies resolved by consensus.

Extraction will then be performed, also in duplicate, using a pre-developed data extraction proforma. For many sources this will likely involve an alternative reading (focused on resilience capacities and factors underpinning these) of papers that conceptualise their analyses around non-resilience-focused frameworks such as the WHO building blocks approach. Resilience themes may be identified inductively (through the material) or deductively (drawing on resilience attributes identified through the resilience theory review).

Risk of bias (quality) assessment [1 change]

Quality assessment will be performed using the Mixed Methods Appraisal Tool (MMAT), a tool which was developed to help facilitate appraisal of public health research studies with multiple study designs and

interventions within a single framework. Appraisal will be performed independently by two members of the study team, with resolution of disagreements through consensus.

Reference: Hong QN, Pluye P, Fàbregues S, Bartlett G, Boardman F, Cargo M, Dagenais P, Gagnon M-P, Griffiths F, Nicolau B, O’Cathain A, Rousseau M-C, Vedel I. Mixed Methods Appraisal Tool (MMAT), version 2018. Registration of Copyright (#1148552), Canadian Intellectual Property Office, Industry Canada..

Strategy for data synthesis [2 changes]

Findings from the review will be narratively synthesised under headings linked to the main study questions, and organised according to the class or type of intervention, based on data gathered from the extraction proforma. Data on classes of intervention will be reported in summary tables outlining actions of each intervention type on key health

system components (e.g. governance, financing, workforce development etc), and variations in implementation processes according to the delivery setting, drawing on information on intervention implementation contained in the included studies. We will prioritise findings from higher quality studies (as assessed using the MMAT tool), and those where more detailed descriptions of intervention context and implementation processes are provided.

Because of the diversity of intervention types, study designs and study contexts likely to be included in the review, it is not anticipated that formal meta-analysis will be either possible or desirable. If data are sufficient in volume to permit this, harvest plots may instead be used to illustrate overall direction of effects arising from specific intervention classes

on key study outcomes. Where quantitative data are reported that are relevant to the primary study outcomes (e.g. change in vaccination coverage rates pre- to post-intervention, change in drop-out rates and related metrics), these may additionally be reported as ranges with median values, provided sufficient background information on the study population is provided to properly contextualise these findings.

Analysis of subgroups or subsets

None planned.

Contact details for further information

Sharif Ismail

sharif.ismail@lshtm.ac.uk

Organisational affiliation of the review

London School of Hygiene and Tropical Medicine

Review team members and their organisational affiliations

Dr Sharif Ismail. London School of Hygiene and Tropical Medicine

Dr Walter Lam. National University of Singapore

Type and method of review

Epidemiologic, Intervention, Narrative synthesis, Prevention, Service delivery, Systematic review

Anticipated or actual start date

02 August 2021

Anticipated completion date

31 December 2021

Funding sources/sponsors

Wellcome Trust

Conflicts of interest

None

Language

English

Country

England, Singapore

Stage of review [1 change]

Review Completed published

Details of final report/publication(s) or preprints if available [1 change]

Ismail SA, Lam ST, Bell SL, Fouad FM, Blanchet K, Borghi J. Strengthening vaccination delivery system resilience in the context of protracted humanitarian crisis: a realist-informed systematic review. medRxiv. 2022 (April 26); doi:

10.1101/2022.04.21.22273340

<https://www.medrxiv.org/content/10.1101/2022.04.21.22273340v2.article->

[info](#)

Subject index terms status

Subject indexing assigned by CRD

Subject index terms

Adolescent; Adult; Altruism; Child; Child Health; Child, Preschool; Communicable Disease Control; Delivery of Health Care; Disasters; Disaster Victims; Healthcare Disparities; Health Status Disparities; Humans; Immunization Programs; Infant; Infant Health; Mass Vaccination; Primary Prevention; Public Health; Relief Work; Vaccination; Vaccination Coverage; Vaccines

Date of registration in PROSPERO

27 September 2021

Date of first submission

13 September 2021

Stage of review at time of this submission [2 changes]

Stage	Started	Completed
Preliminary searches	Yes	Yes
Piloting of the study selection process	Yes	Yes
Formal screening of search results against eligibility criteria	Yes	Yes
Data extraction	Yes	Yes
Risk of bias (quality) assessment	Yes	Yes
Data analysis	Yes	Yes

Revision note

Update submitted to provide details of the preprint published by medRxiv summarising results from this review. A parallel journal submission has been made and is under editorial consideration. If/when a peer-reviewed journal paper from this review is published, a further update to the record will be made providing a link to this.

The record owner confirms that the information they have supplied for this submission is accurate and complete and they understand that deliberate provision of inaccurate information or omission of data may be construed as scientific misconduct.

The record owner confirms that they will update the status of the review when it is completed and will add publication details in due course.

Versions

27 September 2021

30 November 2021

08 May 2022

Appendix 11: Systematic review – list of eligible settings and their eligibility periods

Using data from the UN OCHA, and the humanitarian information gathering portals ReliefWeb and Humanitarianresponse.info, the following countries were categorised as eligible for inclusion as protracted crisis settings during the study period. Note that not all listed countries were eligible for the entire study period; some were eligible only for specific time points (coinciding with periods when they were covered by a HRP or equivalent) – but that all countries had to have had a run of at least 5 years under a response plan of one kind or another to meet the criteria for a protracted crisis setting.

Country	Eligible period(s)	Relevant response plans
<i>Core countries (with country-specific RPs +/- relevant regional RPs of which they formed part)</i>		
Afghanistan	Full duration of the study	Consolidated inter-agency appeals since 1995-96 (and prior to this); consecutive HRPs from 2009-2021
Angola	2001-2002	Consolidated inter-agency appeals, 1995-2002; DRC RRP
Burkina Faso	2013-2021	Consecutive HRPs from 2013-2021
Burundi	2016-2021	Consecutive HRPs from 2016-2021; DRC RRP
Cameroon	2014-2021	Consecutive HRPs from 2014-2021
Chad	2004-2021	Consecutive HRPs from 2004-2021
Central African Republic	2003-2021	Consecutive HRPs from 2003-2021
Democratic Republic of Congo	Full duration of the study	Consecutive HRPs from 1999-2021
Ethiopia	2017-2021	Consecutive HRPs from 2017-2021
Haiti	2010-2021	Consecutive HRPs from 2010-2021
Honduras	2014; 2021-22	Drought emergency response 2014; HRP from 2021-22
Iraq	Full duration of the study	Consolidated inter-agency appeals since at least 1995/6; consecutive Syria 3RPs 2015-2021; consecutive HRPs from 2014-2021
Lebanon	2015-2021	Lebanon war response 2006-7; Syria 3RP 2015-2021; ERP 2021-present
Libya	2011-2021	Consecutive HRPs 2015-2021
Mali	2012-2021	Consecutive HRPs from 2012-2021
Myanmar	2013-2021	Consecutive HRPs from 2013-2021
Niger	2011-2021	Consecutive HRPs from 2011-2021
Nigeria	2014-2021	Consecutive HRPs from 2014-2021
Occupied Palestinian Territories	Full duration of the study	UNRWA presence since 1949; Consecutive HRPs from 2003-2021
Somalia	Full duration of the study	Consecutive HRPs from 1998-2021

South Sudan	2011-2021 (2010 if including HRP prior to independence)	Independence in 2011; Consecutive HRPs from 2010-2021
Sudan	Full duration of the study	Consecutive HRPs from 1993-2021
Syria	2012-2021	Syria HARP 2012 and subsequent domestic plans; 3RP from 2015 onwards.
Ukraine	2014-2021	Consecutive HRPs from 2014-2021
Yemen	2008-2021	Consecutive HRPs from 2008-2021
<i>Countries included as partners in regional refugee response plans only</i>		
Bangladesh	2017-2021	Rohingya RRP 2017-21
Congo	2018-2021	DRC RRP 2018-21
Egypt	2015-2021	Consecutive Syria 3RPs 2015-present
Iran	Full duration of the study	Afghanistan RRP
Jordan	2015-2021	Consecutive Syria 3RPs 2015-present
Kenya	2008-2021	Refugee response plan 2014-2020; Emergency HRP 2008-2013; South Sudan RRP
Pakistan	Full duration of the study	Afghanistan RRP
Rwanda	2018-2021	DRC RRP 2018-21
Tajikistan	Full duration of the study	Afghanistan RRP
Tanzania	2018-2021	DRC RRP 2018-21
Turkey	2015-2021	Consecutive Syria 3RPs 2015-present
Turkmenistan	Full duration of the study	Afghanistan RRP
Uganda	2018-2021	DRC RRP 2018-21; South Sudan RRP
Uzbekistan	Full duration of the study	Afghanistan RRP
Zambia	2018-2021	DRC RRP 2018-21

Abbreviations: 3RP (Syria Crisis only) = Regional Refugee and Resilience Plan; ERP = emergency response plan; HARP = humanitarian assistance response plan; HRP = humanitarian response plan; RRP = regional response plan for refugees.

Appendix 12: Systematic review – sample search strategy

Sample search structure as applied in MEDLINE:

Ovid MEDLINE(R) ALL <1946 to September 03, 2021>

1	exp Immunization, Passive/ or exp Immunization Schedule/ or exp Immunization/ or exp Immunization, Secondary/ or exp Immunization Programs/	192796
2	exp Vaccination/ or exp Mass Vaccination/	92277
3	Vaccines/ or bacterial vaccines/ or toxoids/ or viral vaccines/ or cholera vaccines/ or diphtheria-tetanus vaccine/ or Diphtheria-Tetanus-acellular Pertussis Vaccines/ or Diphtheria-Tetanus-Pertussis Vaccine/ or Diphtheria-Tetanus Vaccine/ or Pertussis vaccine/ or Haemophilus Vaccines/ or Meningococcal Vaccines/ or BCG vaccine/ or tuberculosis vaccines/ or Heptavalent Pneumococcal Conjugate Vaccine/ or Pneumococcal vaccines/ or Papillomavirus vaccines/ or Human Papillomavirus Recombinant Vaccine Quadrivalent, Types 6, 11, 16, 18/ or Measles-Mumps-Rubella Vaccine/ or Measles Vaccine/ or Mumps Vaccine/ or Rubella Vaccine/ or Poliovirus vaccines/ or Poliovirus vaccine, inactivated/ or Poliovirus vaccine, oral/ or Viral Hepatitis Vaccines/ or hepatitis A vaccines/ or hepatitis b vaccines/ or Rotavirus vaccines/ or chickenpox vaccine/ or Influenza Vaccines/ or Typhoid-Paratyphoid Vaccines/ or Tetanus Toxoid/ or Yellow Fever Vaccine/	182764
4	or/1-3	301617
5	exp child/ or exp infant/ or mothers/ or women/ or pregnant women/ or female/	10199346
6	4 and 5	133861
7	((vaccinat* or revaccinat* or immunization or immunisation) adj3 (child* or infant? or newborn? or neonat* or baby or babies or toddler? or woman or women or mother?)).ti,ab.	22878
8	((immunization or immunisation or vaccination) adj (rate* or coverage or uptake or adher* or complian* or drop-out or drop out or access*)).ti,ab.	14272
9	((immunization or immunisation or vaccination) and (system* or service* or delivery or pathway)) adj (readiness or prepared* or responsive* or quality or safe* or resilien* or robust* or adapt* or absorb* or absorp* or transform*)).ti,ab.	101
10	6 or 7 or 8 or 9	144976
11	relief work/ or exp "warfare and armed conflicts"/ or refugees/ or exp disasters/ or genocide/ or ethnic cleansing/ or exp disasters/ or exp disease outbreaks/ or earthquakes/ or volcanic eruptions/ or floods/ or landslides/ or tidal waves/ or tsunamis/ or cyclonic storms/ or droughts/ or starvation/ or famine/ or disaster medicine/	311247
12	(humanitarian* or protracted crisis or protracted crises or complex emergenc* or conflict-affected or conflict affected or fragile countr* or "fragile state* fragile and conflict affected" or "fragile and conflict-affected" or FCAS or insecur* or secur* or transition* countr* or internal displace* or internally displaced person* or displaced population* or mobile population* or forced migrat* or forced migrant or typhoon* or cyclone* or hurricane* or aid work* or financial crisis or economic crisis).hw,kf,ti,ab,cp.	137200
13	11 or 12	436977
14	Developing Countries.sh,kf.	89235

15	(Africa or Asia* or Caribbean or West Indies or South America or Latin America or Central America or Eastern Mediterranean or Americas or Western Pacific).hw,kf,ti,ab,cp.	473656
16	(Afghanistan or Bangladesh or Burkina Faso or Burundi or Central African Republic or CAR or Chad or Colombia or Democratic Republic of Congo or DRC or Eritrea or Ethiopia or Iraq or Lebanon or Mali or Myanmar or Niger or Nigeria or Pakistan or Peru or Somalia or Sudan or South Sudan or Syria or Syrian Arab Republic or Turkey or Uganda or Ukraine or Venezuela or Yemen).ti,ab.	253763
17	(Albania or Algeria or Angola or Argentina or Armenia or Azerbaijan or BBelarus or Belize or Benin or Bhutan or Bolivia or Botswana or Brazil or Bulgaria or Cambodia or Cameroon or Chile or China or Congo or Costa Rica or Cote dlvoire or Ivory Coast or Cuba or Democratic Peoples Republic of Korea or DPRK or North Korea or Djibouti or Dominica or Dominican Republic or Ecuador or Egypt or El Salvador or Gambia or Georgia or Ghana or Guatemala or Guinea or Guinea Bissau or Haiti or Honduras or India or Indonesia or Iran or Jamaica or Jordan or Kazakhstan or Kyrgyzstan or Kyrgyz Republic or Kenya or Laos or Lao PDR or Lao or Liberia or Libya or Madagascar or Malawi or Malaysia or Maldives or Mauritania or Mexico or Mauritania or Moldova or Mongolia or Montenegro or Morocco or Mozambique or Namibia or Nepal or Nicaragua or Republic of North Macedonia or North Macedonia or Palestine or Occupied Territories or Occupied Palestinian Territories or Gaza or West Bank or Papua New Guinea or Paraguay or Philippines or Russia or Russian Federation or Rwanda or Senegal or Serbia or Sierra Leone or Sri Lanka or South Africa or Tajikistan or Tanzania or Timor Leste or Togo or Thailand or Turkmenistan or Uzbekistan or Vietnam or Western Sahara or Zambia or Zimbabwe).ti,ab.	962412
18	((developing or less* developed or under developed or underdeveloped or middle income or low* income or underserved or under served or deprived or poor*) adj (countr* or nation? or population? or world)).ti,ab.	113426
19	((developing or less* developed or under developed or underdeveloped or middle income or low* income) adj (economy or economies)).ti,ab.	697
20	(low* adj (gdp or gnp or gross domestic or gross national)).ti,ab.	292
21	(low adj3 middle adj3 countr*).ti,ab.	21684
22	(Imic or Imics or third world or lami countr*).ti,ab.	9521
23	14 or 15 or 17 or 18 or 19 or 20 or 21 or 22	1386105
24	13 and 23	63847
25	(10 and 24) or (10 and 16)	6413
26	exp health policy/ or exp health services administration/ or health services/ or child care/ or personal health services/ or community health services/ or community health centers/ or health facilities/ or ambulatory care/ or universal health care/ or child health services/ or maternal-child health services/ or telemedicine/ or preventive health services/ or "health services needs and demand"/ or workforce/ or health workforce/ or community health workers/ or exp medical informatics/ or public health informatics/ or exp population surveillance/ or behavioral risk factor surveillance system/ or epidemiological monitoring/ or exp "equipment and supplies"/ or "equipment and supplies utilization"/ or leadership/ or health education/ or healthcare financing/ or financing, government/ or financing,	9868768

	personal/ or induced demand/ or vaccination promotion/ or vaccination campaign/ or communication/ or exp "Health Care Quality, Access, and Evaluation"/	
27	(strengthening or system strengthening or health system strengthening).ti,ab.	35858
28	(social mobili*ation or community mobili*ation or community outreach or community engage* or community health volunteer or outreach or mobile unit or mobile medical unit or mobile team or cash transfer or cct or cash incentive or demand generat*).ti,ab.	28371
29	(logistic* or deliver* or supply chain* or supply-chain* or cold chain* or cold-chain*).ti,ab.	1073065
30	(governance or accountab* or oversight or regulat* or stewardship).ti,ab.	2053531
31	26 or 27 or 28 or 29 or 30	12104943
32	25 and 31	4604
33	limit 32 to (yr="2001 -Current" and (arabic or english or french))	3719

Appendix 13: Systematic review – data extraction template

The data extraction sheet for the review was divided into a series of segments as follows:

Segment 1 – study characteristics and the operational setting:

Study characteristics						CONTEXT			
PAPER CODE	First author	Title	Year of publication	Source type	Study design (where relevant)	Country	Type of crisis	Preventive or outbreak response?	Other contextual features of note [free text]

Segment 2 – Intervention mechanism:

General description of the intervention/programme	Key actors involved	Governance	Funding/financing	Situational awareness
<i>Addressing questions like: what is the intervention, what were the key components, target population, scale/scope etc?</i>	<i>Role of govt, private sector, NGOs, donors, service users, others. Any detail on the perceived legitimacy of these actors, or trust in them from the public.</i>	<i>Details on leadership structure, management, preparedness or planning for future shocks (including things like developing preparedness plans), and in particular any detail on coordination between implementing partners in support of these functions</i>	<i>How was funding for the intervention/programme mobilised? Availability of financial reserves to enable innovation.</i>	<i>Covering surveillance systems, information, monitoring and evaluation</i>

Human resources	Service delivery	Products	Service users	Other (unclassified mechanisms)
<i>Availability, capacity (including surge capacity), capability including through training</i>	<i>Covering modes of service delivery, use of collaterals or redundant pathways; and details of innovation or capacity to innovate in service delivery</i>	<i>Covering issues such as stock procurement, distribution (including pre-positioning in preparation for future vaccine delivery needs, or anticipated outbreaks), actions to strengthen the cold chain</i>	<i>Information on demand-management approaches (such as strategic comms, community mobilisation etc) to try to bolster vaccine uptake</i>	<i>Anything else covered in the article likely to be relevant to resilience in vaccine delivery, not addressed under the themes at left</i>

Segment 3 – outcomes:

OUTCOME		Success factors and constraints	
Outcome measures used	Reported effect(s)/impact(s)	Constraints on the programme or intervention identified by the study authors	Success factors identified by the study authors

A final section of the template collated information on study quality based on assessment using MMAT (see **Appendix 14**).

Appendix 14: Systematic review – quality appraisal template and results

This appendix provides a list of the quality appraisal questions used to inform the systematic review reported in Chapter 7, and reports overall findings from this process spanning all included studies.

		Yes		No		Can't tell	
		n	%	n	%	n	%
SCREENING QUESTIONS	S1. Are there clear research questions?	50	100%	0	0%	0	0%
	S2. Do the collected data allow to address the research questions?	48	96%	1	2%	1	2%
1. QUALITATIVE STUDIES (n=10)	1.1. Is the qualitative approach appropriate to answer the research question?	10	100%	0	0%	0	0%
	1.2. Are the qualitative data collection methods adequate to address the research question?	8	80%	0	0%	2	20%
	1.3. Are the findings adequately derived from the data?	9	90%	0	0%	1	10%
	1.4. Is the interpretation of results sufficiently substantiated by data?	9	90%	1	10%	0	0%
	1.5. Is there coherence between qualitative data sources, collection, analysis and interpretation?	9	90%	0	0%	1	10%
2. RANDOMIZED CONTROLLED TRIALS (n=2)	2.1. Is randomization appropriately performed?	2	100%	0	0%	0	0%
	2.2. Are the groups comparable at baseline?	2	100%	0	0%	0	0%
	2.3. Are there complete outcome data?	2	100%	0	0%	0	0%
	2.4. Are outcome assessors blinded to the intervention provided?	1	50%	1	50%	0	0%
	2.5. Did the participants adhere to the assigned intervention?	2	100%	0	0%	0	0%
3. NON-RANDOMIZED STUDIES (n=5)	3.1. Are the participants representative of the target population?	4	80%	0	0%	1	20%
	3.2. Are measurements appropriate regarding both the outcome and intervention (or exposure)?	5	100%	0	0%	0	0%
	3.3. Are there complete outcome data?	4	80%	0	0%	1	20%
	3.4. Are the confounders accounted for in the design and analysis?	1	20%	4	80%	0	0%
	3.5. During the study period, is the intervention administered (or exposure occurred) as intended?	4	80%	0	0%	1	20%
4. QUANTITATIVE DESCRIPTIVE STUDIES (n=35)	4.1. Is the sampling strategy relevant to address the research question?	34	97%	0	0%	1	3%
	4.2. Is the sample representative of the target population?	23	66%	0	0%	12	34%

	4.3. Are the measurements appropriate?	33	94%	2	6%	0	0%
	4.4. Is the risk of nonresponse bias low?	13	37%	5	14%	17	49%
	4.5. Is the statistical analysis appropriate to answer the research question?	31	89%	2	6%	2	6%
5. MIXED METHODS STUDIES (n=2)	5.1. Is there an adequate rationale for using a mixed methods design to address the research question?	2	100%	0	0%	0	0%
	5.2. Are the different components of the study effectively integrated to answer the research question?	1	50%	1	50%	0	0%
	5.3. Are the outputs of the integration of qualitative and quantitative components adequately interpreted?	1	50%	1	50%	0	0%
	5.4. Are divergences and inconsistencies between quantitative and qualitative results adequately addressed?	1	50%	0	0%	1	50%
	5.5. Do the different components of the study adhere to the quality criteria of each tradition of the methods involved?	1	50%	0	0%	0	0%

Appendix 15: Systematic review – results table

See overleaf.

First author	Intervention class	Country	Antigen	Study design	Context	Mechanism										Outcome(s)		
						Type	System hardware					System software					Description	
							Increased material resource availability	Increased human resource availability and capability	Changes to collaterals and redundancy	Changes to networks and collaboration	Increased flexibility (including decentralisation)	Improved situational awareness and information management	Improved preparedness and planning	Strengthened leadership	Changes to organisational and wider system culture			Improvement population trust
Amani (314)	Campaign	Cameroon	Cholera	Program evaluation	Epidemic response focused on South/South-West of the country in context of insecurity, political crisis, and significant constraints to health service availability, access to Water Sanitation and Hygiene (WASH) and potable drinking water, and livelihood-linked population movements.	Adaptive											Reactive intervention following mobilisation of vaccine doses from the International Coordinating Group (ICG) stockpile. Multi-pronged campaign under oversight of Cameroonian Ministry of Health, involving recruitment and training of vaccinators and social mobilisers. Heavy emphasis on community mobilisation through public messaging, advocacy with religious and community leaders to improve both awareness and trust among	Overall post-campaign vaccination coverage of around 82% but with large geographical and age-based variations (>95% among adolescents in the intervention area, <80% in adults aged >20yrs.

																				affected populations.	
Amani (315)	Campaign	Cameroon	Meningitis	Program evaluation	Conflict-affected setting. Focus on refugee camps in the far North and East of the country, in the context of population movement from the Central African Republic, Chad and Nigeria. Existing health service access in affected areas predominantly supported by international relief agencies.	Adaptive														Preventive mass campaign against Men ACWY targeting children aged 2+, under coordination of national Ministry of Health with international agency and donor financial support. Recruitment and training of vaccinators and community mobilisers. Interactions with religious, community and other camp leaders to increase uptake through improved awareness and trust in service providers.	Overall coverage post-campaign was 81.97% but with large variations by geography and by age, and only two areas achieved the target coverage of >95%. Impact of campaign affected by (i) ongoing population movement into affected areas, and difficulties in tracking new arrivals to ensure vaccination, and (ii) limitations to cold chain capacity given unreliable power supplies.

Aradhi (351)	Health information and surveillance	Iraq	Polio	Program evaluation	Conflict-affected setting. Reports surveillance and immunisation response in Karbala province to confirmed polio cases identified in Baghdad in 2014. Wider health system context in Iraq at this time was influenced by ongoing conflict and included destruction of health facilities, health worker attrition and resulting access constraints, as well financial resourcing shortfalls.	Adaptive											Multi-pronged response including SIAs, household outreach, in-person surveillance work to follow-up on reported AFP cases at facility level, among other activities, to help target vaccination and improve awareness of the importance of immunisation among affected populations.	11 AFP cases were reported from Karbala during the course of the study. Increases in vaccination coverage for OPV3, BCG and measles vaccination were recorded in Karbala following the intervention.
--------------	-------------------------------------	------	-------	--------------------	---	----------	--	--	--	--	--	--	--	--	--	--	---	--

Arale (346)	Governance and coordination	Multiple	Polio	Program evaluation	Complex humanitarian crisis. Intervention addressing polio prevention and control in Kenya and Somalia in context of porous borders, movement of displaced and nomadic populations, insecurity, and limited health service access due to geographical remoteness of locations and limited resourcing from the centre (low funding, workforce recruitment and retention difficulties, low skills base of health workers).	Transformative										Multi-dimensional governance and coordination intervention involving establishment of new cross-border coordination mechanisms, and governance bodies in Kenya and Somalia bringing together national and local partners; harmonisation of recruitment approaches for community health volunteers, and information exchange (on informal border crossing points, migratory routes etc); capacity building for community-based surveillance activities, and other approaches. These activities contributed to improved situational awareness (including hotspot identification) to support vaccination targeting, and improved service delivery through training and standardisation.	Large year-on-year increases in the number of children <5 vaccinated through SIAs linked to the programme, in the number of children aged 12-59 months in receipt of at least 1 dose of polio vaccine, and in the number of AFP cases reported at district level (due to improved case reporting). Progressive increases over the lifecycle of the intervention in the number of community health volunteers recruited, cross-border initiative coordination meetings held, and other intermediate measures.
-------------	-----------------------------	----------	-------	--------------------	--	----------------	--	--	--	--	--	--	--	--	--	--	--

Baptiste (316)	Campaign	Nigeria	Measles	Other	Complex humanitarian crisis. Campaign carried out in northern Nigerian Borno State in context of large, national measles outbreak, and targeting mixed population of internally displaced persons (IDPs), refugees and nomads living in and outside camp settings, but all with limited access to health services through fixed sites. Wider context of ongoing insecurity in Borno linked to the Boko Haram insurgency.	Adaptive											Reactive mass vaccination campaign carried out in two phases under coordination of Nigerian government. Describes use of polio eradication architecture including case-based measles surveillance that is integrated with AFP surveillance for identification of hotspots, supported by newly trained community health workers. Hard-to-reach settlements were accessed with support of military escorts (in event of insecurity) and use of local infrastructure through the GPEI, contributing to improved service reach.	Reported weighted coverage of 85.7% post-campaign (95%CI: 79.6–90.1). Reported coverage was highest in children under 9 months, and 24-35 months at 100% and 92.8% respectively. Study authors note difficulties in coverage estimation in context of ongoing population movement in affected areas.
----------------	----------	---------	---------	-------	--	----------	--	--	--	--	--	--	--	--	--	--	---	--

Bawa (342)	Service integration	Nigeria	Multiple	Program evaluation	Conflict-affected setting. Service changes in response to polio cases reported in Northern States (Bauchi, Borno, Kano and Yobe) in context of ongoing insecurity linked to insurgency, and long-term service access challenges resulting from the challenging terrain, and ongoing population movement (nomadic and forced).	Adaptive											Expanded implementation of existing intervention offering routine immunization together with a basic integrated package of primary healthcare interventions focused on maternal, newborn and child health. This was coordinated through the national polio emergency operations centre, with financial and logistical support from international actors (principally WHO, UNICEF and the BMGF). Use of mobile health teams to reach outlying areas, and monitoring of reach using geographical information tracking. Local engagement through community mobilisers, recruited from affected communities.	At baseline, 19.6% of children in the surveyed intervention area had routine immunisation cards 17.8% were fully immunized. By the end of the survey period, 49.1% had routine immunisation cards and 49.0% were fully immunized. The proportion of zero dose children declined from 11.5% to 4.7%.
------------	---------------------	---------	----------	--------------------	---	----------	--	--	--	--	--	--	--	--	--	--	--	---

Bonfrer (331)	Health financing	Burundi	Multiple	Time series analysis	Conflict-affected setting. At the time of the study Burundi was among the lowest income countries in the world with a GDP of 251 current US\$ per capita, and a health system recovering from civil war. Study focused on implementation of an adaptive intervention at national level.	Adaptive									Intervention acting through changes to facility-level incentive structures to enhance supply of services for various interventions including childhood vaccination. Implementation of performance-based financing, with around 700 health care facilities nationally paid retrospectively based on the quantity and quality of services provided. Bundled services included antenatal care, HIV preventive interventions and delivery of routine immunisations to children under 1 year of age.	Statistically significant increase in uptake of a full vaccination package, including all of its components (BCG, polio, DTP and measles) following performance-based financing introduction, especially among the poorest households.
Bwire (317)	Campaign	Uganda	Cholera	Cross-sectional survey	Complex humanitarian crisis linked primarily to population displacement from neighbouring Democratic Republic of Congo (DRC). Response concerned with refugees living inside and outside refugee camps, but also to address risk of infection spread to host communities in affected areas of northern Uganda.	Adaptive									Reactive, multi-pronged intervention led by Ugandan Ministry of Health, initially incorporating WASH interventions and enhanced surveillance following refugee movement, but then including a vaccination campaign delivered in partnership with WHO, UNICEF and MSF among other partners once the first cholera cases had been identified. Campaign delivered as intensive intervention to 390,000	Estimated coverage of 94% (95% CI 92-95%) with at least one dose, and 78% (76-81%) with two OCV doses following the campaign.

																	households in four targeted areas, using OCV, using a door-to-door approach to improve service access.	
Dadari (336)	Health financing	Multiple	Multiple	Program evaluation	Multiple settings – study evaluates Gavi-supported, health system strengthening programming in 13 countries, including a number meeting the inclusion criteria for the study (Afghanistan, CAR, DRC for example). Large variations in context according to the country concerned.	Adaptive											Health system strengthening activities to promote equity in vaccination delivery across populations – focusing specifically on the use of pro-equity strategies to improve governance. Multi-pronged approaches incorporating strengthened situational awareness systems, human resource capacity building (e.g. peer-support groups for health workers in remote areas), mobilisation efforts using community outreach volunteers and local community champions to improve uptake.	Marginal improvements in national vaccination coverage trends for DTP3 in countries eligible for inclusion in this review over the period 2016-19 (patterns variable by country). Primary outcome focus of the study was on implementation of pro-equity strategies in Gavi partner countries.

Dadgar (318)	Campaign	Afghanistan	Measles	Cross-sectional survey	Conflict-affected setting. Study focused on the period 2001-2, shortly after Coalition operations began. The campaign described continued one that had begun under the Taliban administration but was disrupted by the invasion, on a background of low overall life expectancy, 25% mortality in children under 5, and poor access to primary healthcare services including in the areas of central Afghanistan addressed in this study.	Adaptive										Preventive and reactive vaccination campaign targeting children aged 6mo-12years in central Afghanistan in light of high background measles incidence rates, known low coverage and an ongoing outbreak over the preceding 2 years. Intervention built on architecture previously developed for National Immunisation Days. Children were targeted for vaccination irrespective of prior vaccination status. Campaign coordinated by Ministry of Health with international support from WHO, UNICEF and national and international NGOs. Delivery supported by health worker training and task shifting, use of mobile teams, and administration in community settings including mosques.	77% of children in targeted areas identified as eligible were vaccinated, with reported coverage being lowest in the capital, Kabul (62%). Estimates influenced by significant difficulties in denominator estimation especially in Kabul, where population movement (in and out) had been high in the months leading up to, and following, the invasion.
--------------	----------	-------------	---------	------------------------	---	----------	--	--	--	--	--	--	--	--	--	---	---

Duru (347)	Health workforce	Nigeria	Polio	Program evaluation	Conflict-affected setting. Intervention focused on northern Nigerian states affected by chronic insecurity, but also low health service access, health worker shortages, persistently low vaccination coverage and intermittently reported polio cases. Broader social context affecting vaccination uptake including distrust of public health providers, and religious factors.	Adaptive											Introduction and use of Volunteer Community Mobilisers (VCMs) to support polio vaccination delivery. Supported by multi-level supervision arrangements, VCMs were used to support surveillance through soft intelligence gathering, training to support vaccine logistics and monitoring, and worked with communities (from which they were recruited in the first place) to promote uptake, in partnership with local religious and community leaders.	Principal focus of the intervention was on reducing the number of zero dose children through reductions in missed opportunities for vaccination. Study reports decline in the percentage of missed children, from 4.5% in 2014 to 0.8% in 2018.
Edmond (338)	Service integration	Afghanistan	Multiple	Case-control study	Conflict-affected setting. Describes integrated service delivery in 54 intervention and control districts in central, southern and northern Afghanistan in context of ongoing conflict, poor access to health services, and continuing access challenges, with less than 50% of infants	Adaptive											Expanded use of Mobile Health Teams (MHTs), coordinated through Ministry of Health. MHTs offered services in accordance with the basic package of care agreed nationally, visiting each village within their allocated geographical area intermittently for 1-2 days at a time to deliver primary care services. Services delivered were recorded in electronic health information systems. MHTs had fixed structures, and health workers	Outcome measurement focused on vaccine visits as proxies for uptake. Observed effects differed by antigen. Pentavalent and measles vaccine visits were similar in clinics in the intervention and control districts overall, but there was a statistically significant improvement in receipt of first dose measles vaccine in the intervention sites compared to controls (p=0.02).

					in 2015 in receipt of all vaccinations per the EPI schedule.										received induction and annual refresher training.	
Elsayed (319)	Campaign	Sudan	Measles	Other	Complex humanitarian crisis. Focus on Darfur in Sudan in context of armed conflict over the preceding year, internal displacement and refugee movement affecting >1m people in Sudan and into neighbouring Chad; limited access to WASH, nutrition and basic health services among displaced populations, and measles transmission noted among IDPs in camps in the area.	Adaptive									Reactive vaccination campaign under coordination of Ministry of Health, UNICEF and other partners, but with support from a technical working group including NGOs. The campaign was donor funded, and depended for success on prior negotiation of physical access with parties to the ongoing conflict. Mixed mode of delivery combining fixed sites, temporary posts and mobile outreach. Service delivery integrated with polio vaccination and nutritional supplementation given needs in the target populations. Vaccination activities supported by community mobilisation via	Around 93% of the accessible population (defined on the basis of residence in areas where security allowed a higher degree of access) and 77% of the total target population were vaccinated during the campaign. Coverage was highest in most secure areas (South Darfur), but lowest in parts of the country (West Darfur) where accessibility was most challenging because of security, terrain and other factors.

																mass media and community level activities to bolster demand.	
Engineer (332)	Health financing	Afghanistan	Multiple	RCT	Conflict-affected setting. Introduction of payment for performance (P4P) across 11 provinces in 442 primary care facility level in Afghanistan, in the context of ongoing conflict and instability. Authors note prior experience in Afghanistan in use of P4P to support aspects of contracting for the basic health service package.	Adaptive										Introduction of P4P, with bonuses paid to healthcare workers, based on quality scoring for services delivered linked to information gathered via the health management information system (HMIS). Health facilities also submitted monthly activity reports that were used to inform the size of incentive payments that were made. Managing NGOs retained 10% of the payments centrally. Mode of payment to health workers themselves was determined by facility managers (e.g. blanket or weighted payments)	Similar effects were observed at end-point by comparison with baseline, although for one antigen (pentavalent vaccination) coverage in the pre-post period compared with the comparison areas actually declined (-5.7%, P 0.01). Speculated reasons for limited effects of this intervention include the timeliness of payment to health workers (which was not optimal) and incentivisation that was insufficient to promote the desired performance improvements.

Falisse (333)	Health financing	Burundi	Multiple	Time series analysis	Conflict-affected setting. Describes wider roll out of Burundi in post-conflict period, following an initial period of piloting in 2006-10. Wider health system context was one of chronic under-funded and human resource attrition partly linked to insecurity but also low pay and poor working conditions.	Adaptive										Wider roll out of P4P through facility-level contracting. Intervention involves subsidy payments to facilities based on the volume of services given (but without an explicit service quality premium attached to these payments). The intervention was delivered with funding support from the EU and external technical support, under leadership of national Ministry of Health.	No statistically significant effect in vaccination uptake by antigen (BCG, polio, measles, DTP) or overall in children in the intervention areas following introduction of P4P.
Fekadu (344)	Governance and coordination	Angola	Polio	Program evaluation	Conflict-affected setting. Intervention focuses on efforts to reduce risk of polio transmission in the early post-conflict phase, against background of poor accessibility in affected districts due to insecurity and poor infrastructure. In 1999, Angola had experienced the biggest poliomyelitis epidemic ever recorded in the African Region up to that point, with	Transformative										Partnership intervention with the Angolan military to support polio vaccination delivery and integrated services in security compromised areas, creating wholly new service delivery architecture. Activities were coordinated by an inter-agency coordination committee under the Ministry of Health, but on which military representatives also sat. Included support to administration of oral polio vaccine, vitamin A, deworming agents, social mobilization, monitoring campaign quality,	Presents soft data on outcomes only. Reports that "the average number of children vaccinated per day by a military vaccination team was found to be double than the other volunteer vaccinators. It was also witnessed that there were less number of missed children in military covered area than the areas covered by vaccination volunteers".

					1117 cases and 113 deaths caused by wild poliovirus type 1 and 3.										surveillance and logistics. Military vaccinators were also engaged in community mobilisation activities, mostly through information provision (leafleting etc).	
Habib (343)	Service integration	Pakistan	Polio	RCT	Conflict-affected setting. Integrated polio vaccination and prevention activities delivered in geographical areas specifically chosen for service delivery challenges linked to ongoing insurgency (Bajaur and Karachi) and general insecurity (Kashmore). Wider context of ongoing polio endemicity in Pakistan at the time of the trial.	Transformative									Two intervention arms offered vaccine (OPV or IPV depending on the arm) in addition to comprehensive community mobilisation activities, enhanced communication work, and multiple service delivery modes combining fixed vaccination points as well as mobile "camps". Delivery was via teams comprising both vaccinators and community outreach workers. Prior negotiation with community leaders also occurred to ensure access.	The proportion of fully vaccinated children increased in the two intervention arms compared with the control arm (7.3% [95% CI 4.5–10.0] increase in the first intervention arm vs control; 9.5% [6.9–12.0] increase in second intervention arm vs control; overall p<0.0001).

					in common with only a handful of other countries globally at this time.												
Haddison (360)	Multi-dimensional	Cameroon	Polio	Program evaluation	Conflict-affected setting. Focus of the intervention in far north of the country, against background of insecurity linked to Boko Haram insurgency, and then new political unrest in the northwest and southwest. Health facilities in the affected areas closed for periods owing to insecurity, leading to disruptions to routine immunisation delivery.	Adaptive									Combined "Mother and Child Week" and SIA with overall objective of improving polio vaccination coverage in affected areas, coordinated through an existing central technical group for the EPI programme. Funds were drawn from the Ministry of Health, WHO and UNICEF. Focus on recruitment and training of vaccination workers, and delivery through combination of fixed sites and mobile outreach. Supported by community mobilisation activities including engagement with local religious and community leaders.	Reported administration coverage following the SIA of 89.9% compared to 91.2% following a preceding campaign in 2017 (although data for the earlier campaign are disputed owing to problems with denominator estimation). Notes variations in reported coverage by geographical area and a number of administrative estimates in excess of 100% suggesting inaccurate denominator estimation.	

Hamman-yero (352)	Community engagement and mobilisation	Nigeria	Multiple	Program evaluation	Conflict-affected setting. Describes community engagement activities in four northern Nigerian states (Kano, Bauchi, Borno, and Yobe), some affected by chronic insecurity.	Adaptive												Community engagement and mobilisation intervention bolstering training for existing health service personnel, introducing supervisory checklists for community outreach activities, and working with community and religious leaders to sensitive communities prior to mobile health team visits. Volunteer mobilisers were used to help refer children and pregnant women into services to improve uptake.	OPV coverage for children below 1 year of age was 44% at baseline; this rose to 76% overall by the fourth quarter of the intervention. Large variations in coverage across the geographical areas for the intervention were noted however. Some variations were noted also according to the antigen – third dose pentavalent vaccine coverage rose from 22% to 62% in eligible children in the intervention period over the four quarters.
Idris (340)	Service integration	South Sudan	Multiple	Program evaluation	Complex humanitarian crisis. Intervention implementation in South Sudan in context of ongoing conflict, population movement and high levels of underlying population vulnerability including malnutrition, limited health service access. Prior to the intervention, immunisation services had predominantly been delivered in a vertical way linked to specific	Adaptive												Integration of immunisation and nutrition services in one arm of the intervention, and immunisation with regular paediatric outpatient services in the other arm (these arms were geographically separated by county boundaries). Intervention implementation was supported by a decentralised governance model allowing a degree of discretion for local service managers in how to integrate. The paediatric outpatient department intervention also included use of uptake-promotion	Increases in uptake by antigen were seen for all vaccines delivered across both the nutrition-immunisation service integration sites, and the outpatient-immunisation service integration sites. This effect was more pronounced for first dose pentavalent vaccine in nutrition-immunisation sites that in outpatient-immunisation sites (rate ratio of 1.23 (95% CI 1.12-1.36) but no significant difference was seen for other doses or antigens. Statistically significant improvements in

					programme funding.									measures such as service audits and calendar reminders to patients.	uptake across a range of antigens and doses were noted in nutrition-immunisation integration sites by comparison with baseline.
Kamadjeu (356)	Multi-dimensional	Somalia	Polio	Program evaluation	Complex humanitarian crisis featuring ongoing conflict, population displacement and significant constraints on health service access. Background to the intervention was a large outbreak (189 confirmed wild-type poliovirus 1 cases) of polio in Mogadishu and surrounding districts, and active attempts by actors opposed to the government to ban immunisation among populations living under	Adaptive								SIA's launched to improve OPV uptake among children <5, children <10 and then people of any age successively. Cross-border coordination was supported by coordination meetings in Somalia and in Kenya. Service delivery was via a combination of fixed posts and mobile outreach. This was supported by intensive community engagement to bolster uptake.	Overall coverage of OPV across assessed districts following the campaign varied from 72% to 82%, from a national baseline of <50% in 2012 (prior to the outbreak). By the end of 2013 there had been an unbroken period of 25 weeks with no new WPV cases reported – which the study authors took as indicative of the success of the SIA's.

					their jurisdiction.										
Khan (320)	Campaign	Bangladesh	Multiple	Cross-sectional survey	Complex humanitarian crisis. Focused on displaced Rohingya refugees from neighbouring Myanmar, on background of ongoing conflict, and temporary residence for up to a million refugees in 32 camps scattered across Cox's Bazaar. Most refugees at the time of the study were living in makeshift shelters with limited access to WASH and health interventions.	Adaptive								Vaccination campaign spanning measles, rubella, poliomyelitis and oral cholera vaccine for all individuals living in Cox's Bazaar save for children under the age of 1. The target population group for poliomyelitis vaccination was children aged 0-5.	Reported coverage post-campaign varied from as low as 38% (measles-rubella) to 94% for first dose oral cholera vaccine. Possible reasons for this variation identified by the study team included (i) the short time span for the campaign; (ii) continuing population displacement into Cox's Bazaar during the campaign; and (iii) low awareness amongst the refugee population.

Khetsuriani (357)	Multi-dimensional	Ukraine	Polio	Program evaluation	Conflict-affected setting. Broader context of conflict with Russia (2014) and ongoing political and economic crisis, as well as large declines in coverage across a range of antigens observed since 2009 owing to (i) rising vaccine hesitancy, (ii) declining resource allocations to health in face of ongoing crisis, and (iii) low acceptance among health care workers among other factors.	Adaptive											Multi-dimensional intervention focused on SIAs but supported by a new national governance mechanism bringing together the Ukrainian government with international partners including WHO and UNICEF to support polio vaccination delivery. International partners provided vaccines, technical, financial and logistical support and helped develop advocacy materials to support the SIAs. Wider capacity building included training activities for HCWs but also for journalists to try to improve public messaging, and was supported by wider advocacy and community engagement activities.	Reported OPV coverage increased from 64.4% following the first SIA round to 80.7% following round 3. Effects on public perceptions of the importance of polio vaccination were also documented: awareness of polio among caregivers increased from 68% at the beginning of the outbreak to 89% following SIA round 1, 91% following round 2, and 96% following round 3, mirrored by rising support for the need for supplemental polio vaccination among these populations.
Korir (353)	Community engagement and mobilisation	Nigeria	Polio	Time series analysis	Conflict-affected setting. Intervention implementation in a series of northern Nigerian states including Borno, which at the time of the study was subject to ongoing, insurgency-related insecurity. The broader operating	Adaptive											Micro-level intervention to promote directly observed polio vaccination, accompanied by incentives to draw parents into services to have their children vaccinated. In Borno specifically, members of a military liaison force helped provide security to support vaccination delivery in outlying areas. Incentives to	Overall decline in the number of zero-dose children across all targeted geographical areas from 2.4% in August 2014 (baseline) to 1.1% in May 2016 (endpoint). Steady appreciation in the proportion of children in receipt of four doses or more of OPV in Borno from 75% in 2013 to 86% in 2016. After a cluster of vaccine-

					context in Borno at this time included poor access to health services and health worker attrition owing to a range of factors including low pay.										parents were in kind (soap, milk sachets, noodles, sugar etc) and were supported by community engagement activities with local leaders.	derived polio cases in Borno in 2014 prior to the intervention, 1 further case was reported over the following 24 months.
Lam (321)	Campaign	Iraq	Cholera	Cross-sectional survey	Complex humanitarian crisis. Cholera outbreak in the context of ongoing conflict and high levels of internal displacement in Iraq, and refugee arrivals from neighbouring Syria – the intervention described focused on IDP camps. Displacement settings were frequently overcrowded and with poor access to shelter, WASH and basic health services. The wider health system context in Iraq during this period included financial austerity measures linked to an	Adaptive									Reactive campaign using OCV. A 2-dose campaign was designed targeting >255,000 aged 1 year and over living in IDP camps, refugee camps and other collective settings. Campaign coordination was provided by the Iraqi Ministry of Health working in partnership with international and local actors. Delivery was via a combination of fixed sites and door-to-door outreach and used vaccination teams of fixed composition (1 vaccinator, 1 recorder and 1 “crowd controller”), and included the use of community mobilisers and public information campaigns to draw service users in, although only 10% of those surveyed reported having received any information about	2-dose OCV coverage in the targeted camps was reported as 87% (95% CI 85%–89%). Two-dose OCV coverage in 3 northern governorates targeted (91%; 87%–94%) was higher than that in the 7 southern and central governorates (80%; 77%–82%).

					ongoing economic crisis, which reduced resources for front-line services and contributed to ongoing problems with cholera transmission.										the campaign via these routes.	
Lubogo (322)	Campaign	Somalia	Cholera	Cross-sectional survey	Complex humanitarian crisis. Reactive campaign implemented in context of ongoing conflict, high levels of internal displacement, and in the specific time period of this outbreak, a drought contributing to depleted water sources and further concentration of IDPs in settlements with limited access to WASH and basic health services.	Adaptive									Reactive, two-round vaccination campaign implemented in 11 targeted districts in 2017. The mode of service delivery was via a combination of fixed sites (including schools, health services and public spaces) and door-to-door outreach, to maximise reach, and using a phased approach to focus efforts on a specific district before moving on to the next one. The campaign was preceded by a microplanning exercise led by the Ministry of Health, with international	Reported coverage for two doses of OCV following the campaign was 92.5%, with 7.0% receiving just a single dose. There were large variations in coverage by district, ranging from a maximum of 100%, to as low as 85.9% in one area.

															partner support, and included training for vaccinators, as well as the use of community mobilisers (selected for prior experience through polio eradication work) to promote uptake.	
Mbaeyi (241)	Multi-dimensional	Multiple	Polio	Program evaluation	Complex humanitarian crisis. Describes regional response to a polio outbreak focused on Syria and Iraq, in context of ongoing conflicts in both countries, large cross-border movements and high levels of internal displacement. This occurred against a wider health system context of financial resource constraints, health worker flight and outright destruction of health facilities	Transformative									Governments of eight MENA region countries designated the outbreak a public health emergency and worked with Global Polio Eradication Initiative (GPEI) to develop a regionally-coordinated response plan focused on improved surveillance for AFP cases, and polio vaccine administration to over 27m children regionally. The plan was multi-phase, focusing initially on halting transmission, then identifying importation and transmission hotspots, and finally immunisation	Reported effects varied by country, with generally better evidence of impact in Syria than Iraq (of the two countries most directly affected by conflict). The proportion of non-polio AFP cases among children aged 6–59 months who were reported to have received at least 3 doses of OPV in Syria rose from 82% in 2013 to 94% in 2015, but was unchanged at 93% among Iraqi children of the same age during this period. Of those children aged 6–59 months with non-polio AFP, the proportion who had never received polio vaccination of any form

					(in Syria in particular), and broader governance fragmentation.									system strengthening. Surveillance strengthening work included introduction of EWARN systems in some countries, and improvement to case detection. Access in areas of insecurity was secured through negotiation with community leaders.	decreased from 9% in 2013 to 2% in 2015 in Syria, but rose from 1% to 3% in Iraq over the same period.
Mbaeyi (242)	Multi-dimensional	Syria	Polio	Program evaluation	Conflict-affected setting. Describes response to a new polio outbreak in the context of ongoing Civil War in Syria, widespread destruction of health facilities, health worker attrition and steep declines in population coverage of key antigens since the war began. In addition, bans on vaccination campaigns had intermittently been imposed by governing	Adaptive								Reactive SIAs following identification of polio cases, with activities focused on two governorates (one of which was nominally under the control of Islamic State at the time of the first round). The campaign used OPV for all children <5, but IPV was added for the second round for children aged 2-23 months. Social mobilisation and community engagement activities to improve public perceptions of vaccination were a key mechanism for improving	Reported coverage improved following SIA rounds. Following round 1, coverage in one rose from 79% to 88%, but the change in the second was uncertain owing to large differences between administrative coverage and post-campaign monitoring estimates. Post-campaign monitoring results for the governorate most affected by conflict at the time (Raqqqa) indicated a large increase in second dose OPV coverage from 57%

					<p>authorities in the targeted governorates. In 2010, the national 3-dose OPV coverage estimate by the age of 1 83%, but by 2016 this had fallen to 48%. In addition, the success of previous OPV SIAs following a polio outbreak in 2013-14 appeared to have been limited: reported administrative coverage following these two campaigns was 7% and 23% respectively.</p>									uptake among targeted populations.	in round 1, to 84% in round 3.
Mirza (358)	Multi-dimensional	Somalia	Multiple	Program evaluation	<p>Complex humanitarian crisis. Multi-dimensional intervention implemented in setting of ongoing conflict and population displacement, with extensive damage to infrastructure (including health facilities). In this context, Child Health Days (CHDs) have been used regularly in Somalia to provide outreach</p>	Adaptive								<p>Reducing cost and other access barriers to health services by bringing them to communities in Somalia. CHDs focused on delivery of an integrated service packaged including immunization (especially against measles and tetanus), vitamin A supplementation, oral rehydration therapy, use of insecticide-treated nets, and treatment of malaria. Mechanisms for improving uptake included the use of social mobilisation communities</p>	<p>Analysis of health facility data and reported CHD coverage demonstrated that the proportion of regions with routine measles coverage >50% increased from 10% at baseline (using regular EPI activities only) to >84% in 2009 following the introduction of CHDs alongside regular EPI activities.</p>

															infrastructure, and polio microplanning templates originally developed in Sierra Leone. Comprehensive community engagement work was also carried out including segmenting messages by population groups and translating materials into local languages.	
Ngwa (324)	Campaign	Nigeria	Cholera	Qualitative study	Complex humanitarian crisis, driven primarily by conflict. The study focuses on campaign activities in Borno State in northern Nigeria in the context of an ongoing insurgency, population displacement, and poor health service access especially in outlying areas.	Adaptive									See above.	Reports a case fatality rate by the end of the outbreak of 1.14% - but this is the counterpart study to Ngwa (30) (see further results below)

Nkwogu (345)	Governance and coordination	Nigeria	Polio	Time series analysis	Conflict-affected setting. Focus on Borno State in northern Nigeria, in context of ongoing insecurity linked to insurgency, population displacement and constrained health service access especially in outlying areas.	Adaptive										Intervention focused on promoting civil-military engagement, through deployment of a civilian joint task force (CJTF), described as a “community-initiated security network” supporting the Nigerian military against the Boko Haram insurgency in the north of the country. CJTF members do not necessarily have military training but are drawn from the communities they are working with. CJTF brokering helped to secure agreements with local actors to permit “hit and run” vaccination activities during periods of active conflict, and to support movement of consumables and in-kind incentives to households to support uptake.	The principal effect of the intervention was to improve accessibility and led to a 47% increase in the number of wards perceived as accessible for vaccination staff over the 6 months of the intervention. The percentage of zero-dose children decreased from 8% to 3%.
--------------	-----------------------------	---------	-------	----------------------	---	----------	--	--	--	--	--	--	--	--	--	---	---

<p>Oladeji (341)</p>	<p>Service integration</p>	<p>South Sudan</p>	<p>Multiple</p>	<p>Time series analysis</p>	<p>Complex humanitarian crisis. Intervention implementation in South Sudan in context of ongoing conflict, population movement and high levels of underlying population vulnerability including malnutrition, limited health service access. The specific geographical focus of the intervention was a large IDP camp (Bentiu).</p>	<p>Adaptive</p>											<p>Integration intervention linking outpatient therapeutic program (OTP) centres (for malnutrition interventions) with neighbouring primary healthcare centres where immunisations are typically delivered. Children attended the OTP centres were screened for immunisation status and had any missing vaccinations administered by EPI staff attached to the centres for the duration of the intervention. Funds to support integrated delivery were pooled from nutrition and EPI sources.</p>	<p>The number of children vaccinated across all antigen types reported to have risen a year on from baseline analysis, but coverage estimates (and statistical significance) is not reported. Vaccination dropout rates were assessed to be lower from the OTP centres than from primary healthcare centres in the comparison arm (OR for dropout from OTP was 0.27 in one sector and 0.45 in another – both statistically significant).</p>
<p>Ongwae (339)</p>	<p>Service integration</p>	<p>Nigeria</p>	<p>Polio</p>	<p>Program evaluation</p>	<p>Conflict-affected setting. Focus of the intervention on six northern Nigeria states including Borno, a site of insecurity linked to insurgency at this time. Wider contextual features of the operating context in Borno are as described above for other studies based in this region.</p>	<p>Adaptive</p>											<p>Service delivery supported by MHTs and VCMs to target communities deemed at high risk for polio transmission. Primary mechanism for improving uptake was community engagement: communities were involved in selection of candidate VCMs who were then trained in vaccine administration, surveillance data gathering and other activities by implementing partner organisations.</p>	<p>The percentage of children aged 12–23 months who were fully immunized rose from 19% to 55% over the course of the intervention.</p>

																	Traditional religious and community leaders were also engaged in selection of timing and approach to vaccination outreach activities. MHTs were used to increase reach in remote areas.	
Oteri (349)	Health information and surveillance	Nigeria	Measles	Program evaluation	Conflict-affected setting. The intervention was national but this study includes focused discussion of challenges in implementation in Borno State – a context affected by insurgency-related insecurity as noted for other studies above.	Adaptive											Use of geographical information system (GIS) tools to support denominator estimation for eligible populations for a measles vaccination campaign. Comparison was made between accuracy of GIS-based estimates for northern states including Borno, and a walk-through methodology applied in southern Nigeria. GIS was used to map optimal post locations to ensure that no population settlement was more than 1km away from a site capable of delivering vaccinations – on the assumption that	Mean variance of denominator estimates using GIS for northern states was lower (8.2%) than for southern states where the walk-through methodology was used (19.6%) – although these global estimates hid large variations by state and variation for Borno was particularly high (44.5%). Reasons for this are not clearly described in the study but could include ongoing population displacement after GIS estimates were generated.

															distance was a key barrier to access.	
Peyraud (325)	Campaign	Central African Republic	Multiple	Cross-sectional survey	Conflict-affected setting. Study describes a post-conflict vaccination in CAR, which had been in active conflict from 2012-15. Authors significant health service delivery challenges even before this, with only 48% of primary healthcare facilities having sufficient capacity to deliver EPI vaccines. Conflict-related damage to infrastructure was significant, and included outright destruction of around 25% of health facilities, and plundering	Adaptive									Multi-pronged, multi-antigen campaign designed to provide a new baseline for childhood vaccination coverage, and targeting only children aged <1 in a single prefecture (state). The campaign was delivered as a partnership between the CAR Ministry of Health and MSF. Service delivery was integrated with other interventions dependent on the campaign round: distribution of vitamin A in the first round, nutritional screening in the second round and soap provision in the second and third rounds.	Statistically significant increases in coverage of all included antigens from pre- to post-campaign except for dose 3 pneumococcal vaccine and the yellow fever vaccination (which was not introduced until the third round of the campaign).

					of cold chain and logistics equipment.													
Porta (326)	Campaign	South Sudan	Cholera	Program evaluation	Complex humanitarian crisis. Intervention implementation in South Sudan in context of ongoing conflict, population movement and high levels of underlying population vulnerability including malnutrition, limited health service access. Prior to the intervention, immunisation services had predominantly been delivered in a vertical way linked to specific programme funding.	Adaptive											Preventive mass vaccination campaign for cholera focused on four refugee camps and the surrounding host community population (on the basis of presumed contact between them and refugees e.g. in market settings). Campaign was carried out in two rounds. All people aged >1 yr were included, without intercurrent illness. Service delivery through a combination of fixed site and mobile outreach, where fixed sites were agreed with communities in advance, and outreach activities were designed to focus on common access points e.g. markets. Social mobilisation activities started around a week	Administrative coverage after round 1 was recorded as 84% or more (with some variations by geography) and 53-90% variably for dose 2 depending on the area. Intensity of vaccine administration was greater lower with the fixed site strategy (circa 250 vaccinations per day) whereas the outreach approach vaccinated (500-700 individuals per day).

																before the campaign to increase engagement.	
Rainey (350)	Health information and surveillance	Haiti	Multiple	Program evaluation	Natural disaster – on background of a severe earthquake that struck Haiti in January 2010. This led to the emergence of temporary camps housing an estimated 1.5 million internally displaced children and adults. The wider health system context is described as fragile with long-standing resource shortages (financial and human) and variations in vaccination coverage by	Adaptive										Focused on information gathering around a multi-antigen campaign administering either DTP or tetanus and diphtheria vaccine because a diphtheria outbreak had occurred in Haiti in 2009. A rapid monitoring approach was used to assess uptake following rounds of the campaign – using outreach workers to visit camps and settlements and effectively generate tallies for eligible children who were vaccinated and unvaccinated.	23% of 310 vaccinated camps included in the study had been monitored by the time it concluded. 32 (44%) of those monitored were identified as targets for mop-up vaccination – a much higher than expected fraction likely because of ongoing population movement. However, only six of them had received repeat vaccination when further checks were carried out 6 weeks later. This marginal effect was likely due to lack of capacity among vaccinating teams to respond to need.

					antigen, as well as nearer-term effects linked to destruction of facilities in the earthquake.														
Rouzier (361)	Multi-dimensional	Haiti	Cholera	Program evaluation	Natural disaster – cholera outbreak following the 2010 earthquake, leading to an estimated 650,258 cases and 8,048 as of March 2013 (the time at which the study was conducted). Wider health system context of fragility including limited access to clean water (63% of the population has access to improved water) and sanitation (17% access to improved sanitation), as well as high levels of population need (ongoing epidemics of	Adaptive												Multi-dimensional intervention to deliver cholera vaccination in proof-of-concept intervention targeting residents of urban slums in the Haitian capital. Intervention drew on established position of a NGO serving this population, which set up a new central coordinating committee, novel communication plans, and engagement with community leaders to bolster uptake for OCV. Large investments were made in human resourcing, for which 20% of the total operating staff of the NGO were transferred to support the intervention, and training in vaccine administration and monitoring.	90.8% of the population identified as eligible received two OCV doses, with an estimated overall vaccine coverage among the local population of 74.8%. Dose wastage was very low – 99.9% of doses received by the NGO for the campaign were reported as administered.

					HIV and tuberculosis).														
Sheikh (327)	Campaign	Kenya	Polio	Program evaluation	Complex humanitarian crisis. Reactive campaign in response to seven polio cases in refugee camp residents and six in surrounding communities near the Kenya-Somalia border. Broader context of large, semi-settled refugee population in Kenyan border regions but ongoing displacement linked to conflict in Somalia.	Adaptive												Reactive campaign. Under leadership of the Kenyan Ministry of Health, one national and five subnational OPV campaigns were carried out between May–November 2013, followed by a combined IPV-OPV combined in a campaign directed at approximately 126,000 children aged ≤59 months including those who lived in five refugee camps and surrounding communities near the Kenya-Somalia border. Service delivery was through a combination of fixed sites and mobile outreach and was accompanied by community mobilisation activities informed	Coverage (based on caregiver recall) with OPV and IPV in the December campaign was 92.8% in the refugee camps and 95.8% in surrounding communities. Receipt of OPV in the November campaign was 97.2% in the refugee camps and 97.3% in surrounding communities.

																by lesson learning from the GPEI in Kenya.	
Shuaibu (328)	Campaign	Nigeria	Polio	Program evaluation	Conflict-affected setting. Focus on Yobe and Borno States which reported 46.3% of all polio cases in Nigeria during the study period, but are affected by significant security challenges linked to ongoing insurgency. Wider health system context that some areas of these states are inaccessible, and surveillance is an ongoing challenge. Armed conflict has contributed to destruction of health facilities and	Adaptive										Reactive vaccination campaign involving introduction of IPV alongside three-dose OPV for polio, coordinated through both national and state-level polio emergency control centres. Service delivery was supported by temporary recruitment of vaccinators from the private and voluntary sectors alongside public providers, followed by training in vaccination administration and monitoring. Community mobilisation was supported by targeted messaging and use of community roundtables among other routes.	Administrative coverage in Yobe (OPV) and Borno (IPV) was in excess of 100% following the campaign – suggesting challenges in denominator estimation in the face of ongoing population displacement. IPV coverage in Yobe was 94.9% following the campaign (again, administrative).

					cold chain equipment.										
UNICEF Lebanon (359)	Multi-dimensional	Lebanon	Multiple	Program evaluation	Complex humanitarian crisis, featuring large-scale population influx from Syria and deteriorating economic conditions among others. Wider health system context of provider fragmentation for childhood vaccination, including a prominent role for the private sectors, although refugees and host communities alike are theoretically able to access EPI vaccination free of charge through publicly-supported providers.	Adaptive								SIA's led by Lebanese Ministry of Health and UNICEF, with implementing partner support. Multiple service delivery modes but emphasis on publicly-supported primary healthcare facilities, and dispensaries (pharmacies) supported by the Ministry of Health. Outreach activities were also extensively used to identify zero-dose or undervaccinated children and refer in to fixed sites for vaccine administration.	National coverage estimation for the study period was not available at the time the report was written. However, findings show a progressive increase in the number of zero-dose children identified at each SIA round, from 65% in round 1 (of whom 44% were then vaccinated); 78% during round 2 (51% vaccinated); and 85% in round 3 (55% later vaccinated).

Usman (354)	Community engagement and mobilisation	Nigeria	Polio	Program evaluation	Conflict-affected setting. Implementation in northern states in Nigeria including Borno (see above for references to impact of Boko Haram insurgency). Wider health system setting in which parties to the conflict had targeted and killed polio workers, disrupted polio campaigns, and damaged or destroyed health facilities.	Adaptive										Focusing on expanded community engagement and mobilisation, with a particular focus on tackling perceived misinformation regarding polio vaccination. Intervention implemented with central coordination from the national emergency operations centre for polio. VCMs recruited under the programme are women drawn from the communities they are working with, and work using intensive outreach. Further efforts to strengthen trust by working in partnership with community and religious leaders, among other strategies.	First dose OPV coverage increased from 54.8% in 2014 to 99.0% in 2018 and OPV3 coverage among children aged 12 – 23 months increased from 47.2% in 2014 to 88.4% in 2018. The percentage of fully immunized (all antigens) children rose from 33.0% at baseline in 2014 to 67.0% in 2018, illustrating spillover effects on trust in vaccination in general arising from a community mobilisation effort focused primarily on polio.
Valadez (337)	Health financing	South Sudan	Multiple	Program evaluation	Complex humanitarian crisis. Intervention implementation in South Sudan in context of ongoing conflict, population movement and high levels of underlying population vulnerability including malnutrition, limited health service access. Prior to the intervention, immunisation	Adaptive										Macro-level financing through donors to support health system strengthening in South Sudan in the context of ongoing conflict. Targets for financing included improving human resource capacity at the Ministry of Health, health financing, governance and information systems, and strengthening service delivery and informatics. World Bank financial support specifically	Measles vaccination coverage in children aged 12– 23 months increased by 11.2% (p<0.001) to 49.7%. Child immunisation coverage overall improved significantly by the study end-point (p<0.001) but remained low with about half of the children obtaining a measles vaccination (49.7%, 95% CI ±2.8), and 20.8% in receipt of all childhood

					services had predominantly been delivered in a vertical way linked to specific programme funding.										addressed delivery of a basic health services package including childhood immunisation. Service delivery changes linked to funding included task-shifting and health worker capacity building/training.	immunisations ($\pm 2.3\%$).
Venczel (329)	Campaign	Haiti	Measles	Program evaluation	Complex humanitarian crisis. Broader context in Haiti of high levels of inequality, poverty and globally poor health outcome indicators including low life expectancy and high rates of HIV and tuberculosis. Wider health system context including limited health service access especially for low-income urban populations, and low resourcing for health services in general.	Adaptive									Reactive vaccination campaign in response to emergent measles outbreak, incorporating door-to-door outreach and vaccination, using cadres of vaccinators some of whom were recruited and trained specifically for the campaign. Uptake was independently monitored in parallel to the campaign. The authors note that ability to carry out the campaign depended on mobilisation of significant financial resources almost all of which came from outside Haiti.	Post-campaign monitoring activities indicated coverage in the eligible population (children <10) of 88% but with significant variations in coverage across geographical areas targeted.

Vink (335)	Health financing	Afghanistan	Multiple	Cross-sectional survey	<p>Conflict-affected setting. Wider context in Afghanistan at the time of the study has been described for other included studies above. This intervention focused on a single province – Uruzgan – where 97% of the population lives in rural areas, and health outcomes are poor: 30.4% of pregnant women make use of antenatal services and during their delivery only 23.5% are assisted by a skilled birth attendant; 5.7% of the children aged 12-23 months received all necessary vaccinations prior to the intervention.</p>	Transformative										<p>Public-private partnership between Dutch NGO and private providers in Uruzgan, drawing in 34 private providers to administer childhood vaccinations. This was achieved through introduction of financial incentives to replace lost income for private providers, and was supported by training for health providers in the partnership on vaccination techniques, safety/hygiene methods and monitoring. Facilities were renovated and consumables supplied. A local council for each clinic was also set up to strengthen relations with the community.</p>	<p>DTP3 and MCV1 coverage were significantly higher in intervention villages (73.5%, 66.4% and 69.9% respectively) than in control villages (36.0%, 5.2% and 26.2% respectively; $P < 0.0001$ for all comparisons). The proportion of children being fully vaccinated (excluding BCG) was 54.9% in the PHP villages and 4.9% in the control villages ($P < 0.0001$). A key shift was in the location of vaccination – in control areas, most children were vaccinated in mass campaigns, whereas most in intervention areas were vaccinated at fixed sites.</p>
------------	------------------	-------------	----------	------------------------	--	----------------	--	--	--	--	--	--	--	--	--	--	---

Warigon (355)	Community engagement and mobilisation	Nigeria	Polio	Program evaluation	Conflict-affected setting. Focus on northern Nigerian states including Borno and Yobe (conditions in these areas are as described for other studies included above).	Adaptive												Increasing uptake through community mobilisation and engagement. These included (i) use of in-kind incentives to increase uptake (e.g. foodstuffs); (ii) road shows; (iii) engagement through local religious leaders; (iv) engagement with nomadic communities through nominated intermediaries; (v) outreach into security-compromised zones, and (vi) health camps. All of these activities were focused on improving trust in vaccine providers, and addressing reasons for hesitancy, to increase demand.	The proportion of children with non-polio-associated AFP who received at least four OPV doses rose from 80% in 2012 to 97% in 2014. The proportion of children who were underimmunized – defined as incomplete OPV courses – declined from 17% to 4%. The proportion of zero dose children also declined from 3% to 1% over the time course of the intervention.
WHO/GPEI (330)	Campaign	Multiple	Polio	Other	Multiple sites addressed, but the two of immediate relevance to this study were Somalia (complex humanitarian crisis featuring chronic insecurity with limited access in several areas of the country, and ongoing cross-border and within-border population movement); and Pakistan, particularly in the context of	Adaptive												Change in dosing strategy for OPV, and the implications this has for service delivery. Shorter interval dosing allowed concentration of field supervisors over a shorter time period to provide stronger oversight of vaccination delivery across populations in both settings, but also depended on stronger community engagement and advocacy activities to sensitive communities to the likelihood of multiple dose	For the two case study countries: the shorter interval dosing campaign in Somalia resulted in an early end to polio transmission in these areas by comparison with control areas. In Pakistan, administrative coverage following the campaign was 93%, and 86% by post-campaign monitoring, suggesting high uptake is possible given a higher intensity campaign.

					ongoing conflict following military operations, where Swat valley (the focus of the GPEI intervention discussed) was inaccessible between November 2008 and August 2009.									administration in a campaign context.	
Yehuala-shet (348)	Health workforce	Nigeria	Polio	Program evaluation	Conflict-affected setting. Intervention implemented across northern Nigerian states, but particularly including conflict-affected States in the north of the country such as Borno and Yobe (see context notes for other studies above).	Adaptive								Recruitment and deployment of technical surge capacity to support improved polio vaccine uptake in the context of ongoing transmission particularly in the north of the country. WHO worked with the Ministry of Health and other domestic actors to identify a roster of technical experts, and risk-assess geographical regions for the extent of transmission. These inputs were used to assign (on a biannual basis) technical experts to underperforming areas, so that the most experienced experts were allocated to areas where current performance was poorest. The intervention was underpinned by use	Substantial improvements noted in core polio prevention indicators (e.g. non-polio AFP rate, and stool sample adequacy). The proportion of wards across these areas with >10% children missed by vaccination campaigns decreased from 21% in 2012 to 3% in 2015.

															of variable contract types.	
Yehuala-shet (334)	Health financing	Nigeria	Multiple	Program evaluation	Conflict-affected setting. Intervention implemented nationally, but included conflict-affected States in the north of the country such as Borno and Yobe (see context notes for other studies above).	Adaptive									Introduction of direct payment disbursement mechanism to ensure timely payment of eligible vaccination personnel, improve payment transparency, and release operational funds quickly to local areas to support vaccination delivery. WHO and UNICEF worked with the Nigerian government and with a leading bank to set up disbursement systems, but also established 280 new payment points in less accessible parts of the country to speed up access to funds for health workers operating	Total volume of funds disbursed via this mechanism increased year on year following its introduction. Percentage variation between funds disbursed and accounted for for SIA activities declined to 0% within three years of the introduction of the intervention.

												<p>in these areas. Guidance on budgets and spending allocations were developed and distributed by WHO prior to each round. The aim of the intervention was to promote vaccination delivery through timely financing of local vaccination teams.</p>	
--	--	--	--	--	--	--	--	--	--	--	--	---	--

Appendix 16: Summary of outputs linked to the research project

This appendix lists outputs linked wholly, or in part, to the PhD thesis and project funding from the Wellcome Trust to complete it. The degree of connection to the PhD thesis is indicated by sub-heading below. Preprints are included where relevant, but these are listed only where they have not to date been superseded by published, peer-reviewed journal versions of the same article. Please note that publications listed in section A10.2 were partly or largely carried out while on clinical secondment to support the COVID-19 response, with backing from the Wellcome Trust, which I wish to recognise here with appreciation to the funders.

A16.1 Published journal papers and preprints directly linked to the PhD research

1. ***ISMAIL SA**, Lam ST, Bell, S, Fouad FM, Blanchet K, Borghi J. Strengthening vaccination delivery system resilience in the context of protracted humanitarian crisis: a realist-informed systematic review. *BMC Health Serv Res* 2022;22(1):1-21.
2. ***ISMAIL SA**, Bell S, Chalabi Z, Fouad FM, Mechler R, Tomoaia-Cotisel A, Blanchet K, Borghi J. Conceptualising and assessing health system resilience to shocks: a cross-disciplinary view. *Wellcome Open Res* 2022;7:151.

A16.2 Journal papers and preprints supported in part by funding linked to the project

1. Borghi J, **ISMAIL S**, Hollway J, Kim RE, Sturmberg J, Brown G *et al*. Viewing the global health system as a complex adaptive system—implications for research and practice. *F1000Research*. 2022 Oct 7;11(1147):1147.
2. Bell S, Clarke RM, **ISMAIL SA**, Ojo-Aromokudu O, Naqvi H, Coghill Y, Donovan H, Letley L, Paterson P, Mounier-Jack S. COVID-19 vaccination beliefs, attitudes, and behaviours among health and social care workers in the UK: a mixed-methods study. *PLoS ONE* 2022;17(1):e0260949.
3. ***ISMAIL SA**, Saliba V, Bernal JL, Ramsay ME, Ladhani SN. SARS-CoV-2 infection and transmission in educational settings: a prospective, cross-sectional analysis of infection clusters and outbreaks in England. *Lancet Infect Dis* 2021;21(3):344-53.
4. Shrotri M, van Schalkwyk MC, Post N, Eddy D, Huntley C, Leeman D *et al*. T cell response to SARS-CoV-2 infection in humans: A systematic review. *PLoS ONE* 2021;16(1):e0245532.

5. Post N, Eddy D, Huntley C, van Schalkwyk MC, Shrotri M, Leeman D *et al.* Antibody response to SARS-CoV-2 infection in humans: a systematic review. *PLoS ONE* 2020;15(12):e0244126.
6. Garry S, Abdelmagid N, Baxter L, Roberts N, le Polain de Waroux O, **ISMAIL S**, Ratnayake R, Favas C, Lewis E, Checchi F. Considerations for planning COVID-19 treatment services in humanitarian responses. *Conflict and Health* 2020;14(1):1-1.
7. ***ISMAIL SA**, Huntley C, Post N, Rigby S, Shrotri M, Williams SV, Peacock SJ. Horses for courses? assessing the potential value of a surrogate, point-of-care test for SARS-CoV-2 epidemic control. *Influenza* 2021;15(1):3-6.
8. Naik Y, Baker P, **ISMAIL SA**, Tillmann T, Bash K, Quantz D *et al.* Going upstream—an umbrella review of the macroeconomic determinants of health and health inequalities. *BMC Public Health* 2019;19(1):1-9.

A16.3 Policy reports supported in part by funding linked to the project

1. Noad R, **ISMAIL SA**, Simpson K, Scott JAG (2021). *Scoping report for the UK Vaccine Network: Options for investment in vaccines and vaccine technology for infectious diseases with epidemic potential*. London: London School of Hygiene and Tropical Medicine; doi: 10.17037/PUBS.04665413.

A16.4 Conference presentations and posters directly linked to the PhD

1. ***ISMAIL SA**, Tomoaia-Cotisel A, Noubani A *et al.* “Vaccination delivery system responses to compound shocks: multi-level pathways influencing system resilience in Lebanon”. American Public Health Association Annual Meeting, Boston, United States, 6th-9th November 2022 [oral presentation].
2. ***ISMAIL SA**, Tomoaia-Cotisel A, Noubani A *et al.* “Vaccination delivery system responses to compound shocks: multi-level pathways influencing system resilience in Lebanon”. 7th Global Symposium on Health Systems Research, Bogota, Colombia, 31st October-4th November 2022 [oral presentation].
3. ***ISMAIL SA**, Tomoaia-Cotisel A, Noubani A *et al.* “Vaccination delivery system responses to compound shocks: multi-level pathways influencing system resilience in Lebanon”. System Dynamics Society Annual Conference, Frankfurt, Germany, 18th-22nd July 2022 [oral presentation].

4. ***ISMAIL SA**, Tomoaia-Cotisel A, Noubani A *et al.* "Vaccination delivery system responses to compound shocks: the limits of system resilience in Lebanon". Poster P1901 (subtheme 10c – General Vaccinology), European Congress of Clinical Microbiology and Infectious Disease, Lisbon, Portugal, 23rd-26th April 2022 [poster].
5. ***ISMAIL SA**, Tomoaia-Cotisel A, Noubani A, Fouad FM, Bell S, Blanchet K, Borghi J. "Vaccination delivery system responses to compound shocks: multi-level pathways influencing system resilience in Lebanon". Student Prize Competition Presentation, UK System Dynamics Society Chapter Conference 2022, University of Strathclyde, Glasgow, Scotland, 21st-22nd April 2022 [oral presentation].
6. ***ISMAIL SA**, Fouad FM, Bell S, Blanchet K, Borghi J. "Governance, legitimacy and health service resilience in the context of protracted crisis: routine vaccination delivery in Lebanon". Poster POL 014, Consortium of Universities for Global Health conference 2022 (online), 28th March-1st April 2022 [poster].
7. ***ISMAIL SA**, Tomoaia-Cotisel A, Noubani A, Fouad FM, Bell S, Blanchet K, Borghi J. "Health system responses to compound shocks – the limits of vaccination delivery system resilience in Lebanon". Poster SHS 058, Consortium of Universities for Global Health conference 2022 (online), 28th March-1st April 2022 [poster].
8. ***ISMAIL SA**, Cassidy R, Tomoaia-Cotisel A *et al.* A critical reflection on approaches to problem articulation for system dynamics modelling in health policy analysis projects. International System Dynamics Conference, University of Bergen, Bergen, Norway, 19th-23rd July 2020 [oral presentation]
9. ***ISMAIL SA**, Tomoaia-Cotisel A, Fouad FM *et al.* Strengthening national vaccination delivery systems for displaced populations in protracted humanitarian crises: reflections on applying system dynamics methods in Lebanon. International System Dynamics Conference, University of Bergen, Bergen, Norway, 19th-23rd July 2020 [oral presentation]