Capturing Complexities in Urban Maternal and Newborn Healthcare Systems: A Scoping Review on Application of System Dynamics Modelling

Additional file I: The search strategy for each database

Database	Search strategy
PubMed	1. system dynamic*[Title/Abstract] OR "stock and flow diagram"[Title/Abstract:~0] OR "causal loop diagram"[Title/Abstract:~0] 2. model*[Title/Abstract] OR approach*[Title/Abstract] OR analysis[Title/Abstract] OR science*[Title/Abstract] OR theory[Title/Abstract] OR method[Title/Abstract] OR framework[Title/Abstract] OR based[Title/Abstract] 3. #1 AND #2 4. healthcare or health-care or health care or health polic* or medical care or wellness or public health[All Fields] 5. (# 3 AND #4) Filters: English, French
Web of science	1. TS=("system dynamic*" or “stock and flow diagram*” or “causal loop diagram*”) 2. TS=(model* or approach* or analysis or science* or theory or method or framework or based) 3. #1 AND #2 4. ALL=(health or healthcare or health-care or health care or health polic* or medical care or wellness or public health) 5. (# 3 AND #4) AND English or French (Languages)
Cochrane Library	1. (system dynamic* or “stock and flow diagram” or “causal loop diagram”):ti,ab,kw 2. (model* or approach* or analysis or science* or theory or method or framework or based):ti,ab,kw 3. #1 AND #2 4. (health or healthcare or health polic* or medical care or wellness or public health): All text 5. # 3 AND #4 AND English:la OR French:la
Scopus	1. TITLE-ABS-KEY ("system dynamic*" OR "stock and flow diagram*" OR "causal loop diagram*") 2. TITLE-ABS-KEY (model* OR approach* OR analysis OR science* OR theory OR method OR framework OR based) 3. #1 W/0 #2 4. ALL (health OR healthcare OR "health polic*" OR "medical care" OR wellness OR "public health") 5. # 3 AND #4 AND (LIMIT-TO (LANGUAGE , "English") OR LIMIT-TO (LANGUAGE , "French")
Embase	1. 'system dynamic*':ti,ab,kw OR 'stock and flow diagram*':ti,ab,kw OR 'causal loop diagram*':ti,ab,kw 2. model*:ti,ab,kw OR approach*:ti,ab,kw OR analysis:ti,ab,kw OR science*:ti,ab,kw OR theory:ti,ab,kw OR method:ti,ab,kw OR framework:ti,ab,kw OR based:ti,ab,kw 3. #1 AND #2 4. health OR healthcare OR 'health polic*' OR 'medical care' OR wellness OR 'public health': *free text* 5. # 3 AND #4 AND ([english]/lim OR [french]/lim)

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Additional file II

Variables included in the Urban Maternal and Newborn Health (MNH) Causal Loop Diagram (CLD)

Table 1. Micro-Level variables with descriptions and influencing links

Variable name	Variable description	Influenced by	+/-	Influences	+/-
Awareness of maternity services	Level of knowledge among women about availability, benefits, and location of maternal health services	Religion/beliefs and myths	–	Maternal and newborn service delivery (uptake)	+
		Family member influence	+		
		Health education by health workers	+		
		Influence from other women	+		
		Literacy and education level	+		
		Mobilisation campaigns	+		
Health status of women	Overall physical and mental health condition of women before, during, and after pregnancy	Feeding and nutrition	+	Maternal and newborn healthcare outcomes	+
		Maternal and newborn healthcare outcomes	+		
		Abusive relationship	–		
		Household wealth	+		
		Untreated diseases	–		
		Teenage pregnancy	–		
		Postpartum depression	–		
Feeding and nutrition	Adequacy and quality of food intake during pregnancy and postpartum period	Household wealth	+	Health status of women	+
		Motivated health workers	+		
		Family member influence	+		
Hygiene and household environment	Cleanliness, sanitation, and living conditions affecting maternal and newborn health	Household wealth	+		
Maternal and newborn service delivery (utilisation)	Use of antenatal, delivery, and postnatal services at health facilities	Awareness of maternity services	+	Maternal and newborn healthcare outcomes	+
		Motivated health workers	+	Health status of women	+
		Equipment and drug availability	+	Healthcare distrust	–

		Timely adequate referrals	+		
		Women receiving incentivised services	+		
		Health care distrust	–		
Health care distrust	Lack of confidence in health facilities and providers	Misreported risks	+	Maternal and newborn service delivery	–
		Maternal and newborn service delivery	–		
Misreported risks	Inaccurate or misleading communication of health risks that distorts women's understanding of maternal and newborn care needs and services.			Health care distrust	+
Family member influence	The effect of relatives' opinions, decisions, and support on a woman's choices about maternal and newborn healthcare			Awareness of maternity services	+
				Feeding and nutrition	+
Abusive relationship	Exposure to domestic violence or controlling partner behaviour			Health status of women	–
Religion/beliefs and myths	Cultural or religious norms and misconceptions that shape perceptions and decisions about maternal and newborn healthcare.			Awareness of maternity services	+
Untreated diseases	Existing medical conditions that remain unmanaged or without appropriate care during pregnancy or postpartum.			Health status of women	–
Teenage pregnancy	Pregnancy occurring in girls aged 10–19 years, often associated with higher health and social risks.			Health status of women	–
Postpartum depression	A mood disorder occurring after childbirth, characterized by persistent sadness, anxiety, or emotional distress			Health status of women	–
Household wealth	The economic resources and assets available to a household that influence access to healthcare and living conditions.			Health status of women	+
				Feeding and nutrition	+
				Hygiene and household environment	+
Literacy and education level	The ability of women to read, understand, and use health information, influenced by their level of formal education.			Awareness of maternity services	+

Influence from other women	Peer influence from other women in the community regarding service use	Awareness of maternity services	+

Table 2. Meso-Level variables with descriptions and influencing links

Variable name	Variable description	Influenced by	+/-	Influences	+/-
Motivated health workers	Degree of commitment, morale, and willingness of providers to deliver quality care	Availability of incentives for health workers	+	Maternal and newborn service delivery	+
		Training, recruitment, remuneration	+	Feeding and nutrition	+
		Staffing shortage	–		
Training, recruitment, remuneration	Processes ensuring adequate staffing levels, fair pay, and skill development	Leadership and team building	+	Motivated health workers	+
Staffing shortage	Insufficient number of health workers relative to service demand	Workload	+	Motivated health workers	–
Workload	The amount of tasks and patient care demands on health workers			Staffing shortage	+
Health education by health workers	Efforts by health workers to provide guidance and information on health practices, influencing maternal and newborn service uptake			Awareness of maternity services	+

Mobilisation/campaigns	Organized efforts to engage communities, raise awareness, and encourage participation in maternal and newborn health services, influencing service utilization and health outcomes			Awareness of maternity services	+
Availability of incentives for health workers	The presence of financial or non-financial rewards that motivate health workers, influencing their commitment, morale, and willingness to deliver quality care.	Leadership and team building	+	Motivated health workers	+
Leadership and team building	Actions and strategies by managers to guide, support, and strengthen collaboration among health workers, influencing staffing, motivation, and service delivery.	Planning resource allocation (Funding)	+	Availability of incentives for health workers	+
				Training, recruitment, remuneration	+
				Availability of transport/ambulances	+
Supply of equipment	Procurement and distribution of essential medical equipment			Equipment and drug availability	–
Equipment and drug availability	Availability of essential medicines and functioning equipment at facilities	Supply of equipment	–	Maternal and newborn service delivery	+

		NGO support	+		
		Drug supply	–		
Availability of transport/ambulances	Access to reliable emergency transportation for maternal referrals	Planning and resource allocation (Funding)	+	Timely adequate referrals	+
		Leadership and team building	+		
Timely adequate referrals	Efficient transfer of patients needing higher-level care	Availability of transport/ambulances	+	Maternal and newborn healthcare outcomes	+
		Traffic	–		
		Ineffective referral	–		
NGO support	Assistance from non-governmental organisations in funding, logistics, or training			Equipment and drug availability	+
Drug supply	Provision of essential medicines and medical supplies, influencing the quality and continuity of health services	Pandemic	+	Equipment and drug availability	–
Traffic	Transportation and road conditions affecting the ability of women and health workers to reach health facilities.			Timely adequate referrals	–

Ineffective referral	Poorly coordinated systems for directing patients to appropriate levels of care, reducing timely treatment and overall health service efficiency.	Timely adequate referrals	–
Women receiving incentivised services	Women accessing care due to financial or material incentives	Maternal and newborn service delivery	+
Pandemic	Widespread infectious disease outbreak disrupting health systems	Drug supply	–

Table 3. Macro-Level variables with descriptions and influencing links

Variable name	Variable description	Influenced by	+/-	Influences	+/-
Leadership and Governance	Effectiveness of health sector leadership, accountability, and coordination mechanisms	Political will and accountability	+	Planning and resource allocation (Funding)	+
		Poor leadership	–	Availability of maternal and newborn guidelines	+
		Policy resistance	–	Number of policy changes	+
Policy gaps	Absence or weakness of policies addressing maternal and newborn health	Policy resistance	+	Poor leadership	+
Policy resistance	Institutional or stakeholder opposition to policy implementation or reform	Number of policy changes	+	Policy gaps	–
				Leadership and governance	–

Planning and resource allocation (Funding)	Budgeting and distribution of financial resources to health services	Leadership and Governance	+	Availability of transport/ambulances	+
				Leadership and team building	+
Availability of maternal and newborn guidelines	Existence and accessibility of up-to-date clinical protocols, standards, and referral guidelines for maternal and newborn care.	Leadership and Governance	+		
Number of policy changes	Frequency of reforms or regulatory modifications in the health system	Leadership and governance	+	Policy resistance	+
Political will and accountability	Commitment of political actors to prioritise and monitor maternal health	Leadership and Governance	+		
Poor leadership	Ineffective management marked by weak accountability, poor coordination, and inadequate decision-making.	Policy gaps	+	Leadership and governance	–

Table 4: The outcomes explored in different healthcare fields

Healthcare Fields	Outcome	Frequency (%)
Primary health care	Dual practice among government health workers	2 (9.37)
	Intersection between health, health literacy and local government	2 (6.25)
	Medical reform	2 (6.25)
	Quantified impact of heat waves on mortality, evaluating mitigation measures (hospital bed readiness, income support)	1 (3.12)
	Resilience mechanisms in healthcare service delivery	1 (3.12)
	Urban Health Indicator (UHI) tools	1 (3.12)
Maternal and newborn healthcare	Neonatal mortality	1 (3.12)
	Maternal health demand	1 (3.12)
	Maternal health performance	1 (3.12)

	Neonatal mortality, maternal health service	1 (3.12)
	Racial disparities	1 (3.12)
	Identification of structural racism	1 (3.12)
	Prenatal diet quality	1 (3.12)
	Payment for performance on maternal and child health services	1 (3.12)
	Maternity pathway, caesarean section reduction	1 (3.12)
Healthcare system resilience	Health system resilience in the face of crisis	1 (3.12)
	Pressures in health and social care	1 (3.12)
	Urban resilience mechanism	1 (3.12)
	health outcomes and expenditures	1 (3.12)
Healthcare promotion and prevention	Health promotion and chronic disease outcomes	1 (3.12)
	Health promotion policy and practice	1 (3.12)
	Healthcare coordination for youth experiencing homelessness	1 (3.12)
Disease control	Tuberculosis (TB) policy	1 (3.12)
	Immunization coverage	1 (3.12)
	Barriers/enablers to cholera intervention implementation	1 (3.12)
	TB transmission and context-specific IPC interventions	1 (3.12)
	Obesity prevention	1 (3.12)
Mental health	Mental health status	1 (3.12)