Corresponding author: alys.mcalpine@lshtm.ac.uk

MyTh MaP-IN ABM ODD+2D protocol

This document follows the ODD+2D protocol to document the *Myanmar-Thailand Migration Planning & Intermediary Networks* agent-based model (MyTh MaP-IN ABM) along with some additional sections on the verification, sensitivity analysis, and validation of the model (A.7.18-A.7.20). The document is divided into three parts.

PART 1. Model summary and team contributions

Part 1 is a short summary of the model and modelling team.

PART 2. ODD+2D Protocol

Part 2 is the ODD+2D[1] protocol for the MyTh MaP-IN ABM (see Table 1).

Table 1. ODD+2D sections

Overview	**A.7.1**	**Purpose and audience**
	A.7.2	**Entities, properties, and scales**
	A.7.3	**Process overview and scheduling**
Design Concepts (+Decisions)	**A.7.4**	**Theoretical and empirical background**
	A.7.5	**Individual decision-making**
	A.7.6	**Learning**
	A.7.7	**Individual sensing**
	A.7.8	**Individual prediction**
	A.7.9	**Interaction**
	A.7.10	**Collectives**
	A.7.11	**Heterogeneity**
	A.7.12	**Stochasticity**
	A.7.13	**Observation**
Details (+Data)	**A.7.14**	**Implementation details**
	A.7.15	**Initialization**
	A.7.16	**Input data**
	A.7.17	**Sub-models**

PART 3. Verification, sensitivity analysis, and validation

Part 3 provides details on the verification, sensitivity analysis, and validation.

A.7.18 Verification

A.7.19 Sensitivity analysis

A.7.20 Validation

[1] The ODD+2D protocol (1) is the 2018 extension the original 2006 ODD protocol later updated in 2010 (2). The ODD protocol provides a standard for describing and sharing ABMs. In 2013 the first extension, the ODD+D protocol (3), added new questions on decision-making process. Then this 2018 extension, the ODD+2D protocol, added section on 'Input Data'. This protocol helps facilitate transparent, comprehendible, and consistent ABM dissemination so other modellers can more easily assess and reproduce the ABM.

Corresponding author: alys.mcalpine@lshtm.ac.uk

Part 1. Model summary and team contributions

Model name – Myanmar-**Th**ailand **M**igr**a**tion **P**lanning & **I**ntermediary **N**etworks (MyTh MaP-IN)

Model type – agent-based model (ABM)

Model rules – heuristic IF-THEN rules, including some probabilistic rules

Empirical phenomenon – Low wage labour migration planning and execution in the Myanmar-Thailand corridor, including the social and intermediary network interactions that facilitate migration pathways and emergent levels of precarity.

Modelling team – The interdisciplinary team of researchers and modellers that contributed to this ABM include a computational social scientist, computer programmer, mathematical modeller, social epidemiologist, and behavioural and social scientist. This group collectively possesses a specialised set of technical, theoretical, and empirical knowledge to inform the MyTh MaP-IN ABM. The design and execution of the work was led and completed by Alys McAlpine (**AM**) as part of her Doctoral studies with technical and design contributions from Luke Demarest (**LD**) and advisory support from Dr Zaid Chalabi (**ZC**), Dr Ligia Kiss (**LK**), and Prof Cathy Zimmerman (**CZ**).

Team member contributions in brief: **AM** completed the data collection, ABM design, ABM analysis and write up; **LD** programmed the model and data visualisations; **ZC** reviewed the translation of the conceptual model and empirical analysis into model-based rules; **LK** and **CZ** reviewed the model assumptions and rules for domain accuracy.

Team member backgrounds and contributions in more detail:

1. **Lead Modeler –** Alys McAlpine is a Doctoral Candidate in the Public Health and Policy faculty at the London School of Hygiene and Tropical Medicine (LSHTM). She has spent her academic career studying the drivers of labour exploitation and gender-based violence (GBV) in migrant populations. During her doctorate, her training focused on computational social science and complex systems methodologies.

- **AM completed the following research activities for this ABM work:** research design; data collection and fieldwork management; data cleaning; empirical mixed-methods analysis to inform the ABM; development of the model conceptual framework; design of the model structure, entities, and rules; supervision of the model programmer's translation of the conceptual model and rules into the computational model; verification of the ABM sub-models; scenario analysis; sensitivity analysis; validation; and write up.

2. **Computer Programmer –** Luke Demarest is a computer programmer and computational artist. He is an Associate Lecturer in Graphic Communication Design at Central Saint Martins, University of the Arts London. He is proficient in creating interactive data visualizations and object-oriented simulations.
    - **LD made the following contributions to this ABM work:** programmed the digital participatory egocentric network tool that was used for data collection (4); programmed the network data visualization interfaces to inform the ABM parameters (4); contributed to the content and design of model documentation, figures, and tables; programmed the MyTh MaP-IN ABM; and supported on model verification steps.
3. **Mathematical modeller –** Dr Zaid Chalabi is an Honorary Associate Professor in Mathematical Modelling at University College London (UCL) and at LSHTM. He is an expert on the use of ABM and other mathematical modelling for complex systems research. Dr Chalabi was an essential member of AM's PhD Advisory Committee and the lead advisor for this ABM work.
    - **ZC advised and supported this ABM work in the following ways:** trained AM on ABM methods; directed AM's reading and scholarship on ABM; was the senior author on the corresponding ABM systematic review (5); instructed and reviewed AM's work developing the heuristic-based model rules; guided and quality checked AM and LD's translation of the conceptual model into the

computational model; guided AM on ABM methods of verification, validation, sensitivity analysis, and outcome analysis.

4. **Social epidemiologist & Migration and trafficking subject expert –** Dr Ligia Kiss is an Associate Professor in social epidemiology at UCL's Institute for Global Health and holds an honorary post at LSHTM. She is a domain expert on violence, human trafficking and health and has methodological expertise on the design and evaluation of complex interventions in a range of geographic regions. Dr Kiss is one of two Co-Supervisors for AM's PhD.
    - **LK advised on the ABM development, in the following ways**: guided AM's reading on complex systems theory and methods; gave valuable insights on the opportunity to use complex systems modelling for the migration and violence domain area; acted as the second reviewer and co-author on the corresponding ABM systematic review (5); reviewed the primary mixed-methods analysis and findings that inform the ABM; advised the empirical and theoretical underpinnings of the conceptual model during design and development; and reviewed the domain relevance of the key model entities identified for the scenario and sensitivity analysis.
5. **Behavioural and social scientist & Migration and trafficking subject expert–** Prof Cathy Zimmerman is a Professor in Migration, Violence and Health at LSHTM. She is a subject expert on violence, human trafficking, and health. She leads a global portfolio of applied research to inform evidence-based safe migration and trafficking prevention policy and practice. Prof Zimmerman is one of two Co-Supervisor for AM's PhD.
    - **CZ advised on the ABM development, in the following ways:** as a contributing author on the ABM systematic review (5); reviewed the primary mixed-methods analysis and findings that inform the ABM; advised the empirical and theoretical underpinnings of the conceptual model during design and development; and reviewed the domain relevance of the key model entities identified for the scenario and sensitivity analysis.

Corresponding author: alys.mcalpine@lshtm.ac.uk

Part 2a. ODD+2D Protocol – Overview

A.7.1 Purpose and audience

Purpose – This empirical-based ABM is an exploratory descriptive model (6) that contributes new conceptual knowledge of how low-wage labour migration pathways are planned and executed in highly irregular migration corridors, such as the Myanmar-Thailand corridor. The model aims to describe the complex migration pathways and emergent migration networks, and then offer a preliminary explanation about how individual levels of *hyper*-precarity emerge across different pathways.

This ABM is a tool and 'touchstone' for exploring, debating, and understanding the system of actors and range of actions and interactions that facilitate migration. There is currently a limited body of context-specific evidence that identifies migration mediation processes in highly irregular labour migration corridors or how these processes might influence labour migration outcomes (7, 8). This substantial research gap limits our understanding of the variety and complexity of migration experiences and outcomes. Understanding how migrants engage with labour migration systems is essential to explaining complex causal chains within these systems, which might be possible leverage points for intervention. This primarily descriptive ABM aims to be the first in a series of ABMs aiming to explain and predict the effectiveness of safe migration interventions (i.e., counterfactual scenario testing).

This empirically informed ABM models the Myanmar-Thailand migration corridor and is potentially relevant to other migration corridors between counties with highly porous borders and high rates of irregular migration (e.g., Cambodia-Thailand, Guatemala-Mexico, Mexico-USA, etc.).

Methodological contribution – In addition to the empirical purpose, a further aim of this ABM is to contribute methodological 'proof of concept' to advance the use of mixed-methods-informed ABMs for future intervention research. This work aims to advance the use of ABM to describe

the complex, nonlinear, dynamic, and multi-level (hierarchical) systems, but also explain causal mechanisms and test assumptions for intervention design. Agent-based modelling has not yet been used to inform, design, and test safer labour migration interventions (5) the way it has been used for other public health interventions, such as childhood obesity (9), vaccination strategies (10), controlling influenza pandemic (11), among others (12, 13). This computer simulation method offers a more feasible, less costly, and more ethical approach to intervention research that would be especially well suited to intervention development with hard-to-reach populations of migrants.

Model audience (or 'users') – This first descriptive ABM is designed for a wide audience of users situated at various levels of the labour migration system (e.g., practitioners, policy makers, donors, and other researchers). It is a tool for questioning, exploring, and understanding the relationship between migration decision making, networks, and pathways, as well as individual outcomes of precarity. This descriptive model can be used as a touchstone for debating controversial theories of change around 'regular' migration.

Examples of possible users and uses include:

Practitioners designing safe migration and anti-trafficking interventions can use this ABM as a tool to explore the full scope of the system for intervention opportunities and even test the sensitivity of the described system to certain parameter changes (e.g., locations of agency offices, change in Migrant's thresholds or motivations to migrate). Future iterations of this model could then be used to test interventions (i.e., counterfactuals).

Legislatures drafting migration and/or low wage labour policy can use this ABM to explore systems wide policy agendas. Future iterations could include new policy initiatives as an exogenous force on labour migration systems that may result in both foreseen and unforeseen changes in individuals' behaviours (i.e., agent adaptation).

Corresponding author: alys.mcalpine@lshtm.ac.uk

Donors prioritizing how to invest finite resources can use this ABM to identify the range of system components to address and how these components relate to each other. Again, future iterations of this ABM could be used to identify promising leverage points in the system and to identify any barriers to intervention success that need to be addressed simultaneously (i.e., interaction of system elements).

Researchers conducting safe migration intervention research can use this ABM to identify gaps in current understanding of how the system works to better inform future iterations of similar complex system models. This descriptive model, with thoughtful adaptations, can be used as the starting structure to build more explanatory and predictive ABMs.

Corresponding author: alys.mcalpine@lshtm.ac.uk

A.7.2 Entities, properties, and scales

Model Entities – MyTh MaP-IN has three **agent entities** or 'classes' (*Migrant*, *Intermediary*, *Employer*) and three **environment entities** or 'areas' (origin, destination, border). The *Intermediary* class is divided further into five 'extended classes' (i.e., sub-groups of agents that inherit the parent class properties). Likewise, some of the environment entities have smaller 'sub-areas' or contain 'proto-agents' (*passport offices, agencies, crossings*).

Agent entities

Figure 1, repeated below from the main paper, details the visual features of the agent classes and sub-groupings (*Migrant* **states**, *Intermediary* **extended-classes**, *Employer* **sectors**).

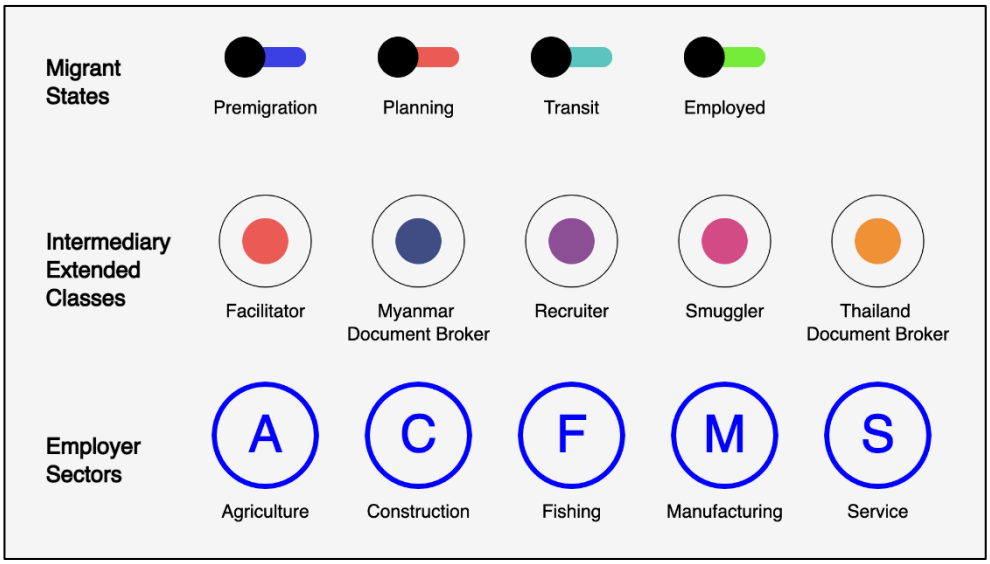


Figure 1. Agent visuals by type and sub-group

N.B. Myanmar and Thai Document-Brokers look identical to signal their similar roles. They are distinguished by which side of the border they are on.

Agent classes, extended classes, and objects:

1. *Migrant* class – each instance contains a *migrations* array (size 0-many):
    i. *Migration* – each instance is a unique migration containing a *plan*:
        a. *plan* – group of properties describing intended *migration*
2. *Intermediary* class – five extension classes: Facilitator, Recruiter, Smuggler, Myanmar Document-Broker, and Thailand Document-Broker
3. *Employer* class – each instance is assigned to one of five work sectors: Agriculture, Construction, Fishing, Manufacturing, and Service

The properties, behaviours, and interactions that define the distinctions between these agent classes and extended classes are described in detail throughout this ODD+2D protocol.

Environment entities

Figure 2 presents the environment (i.e., model space), which is an abstract representation of real geographic places of emigration and immigration in the Myanmar-Thailand migration corridor.

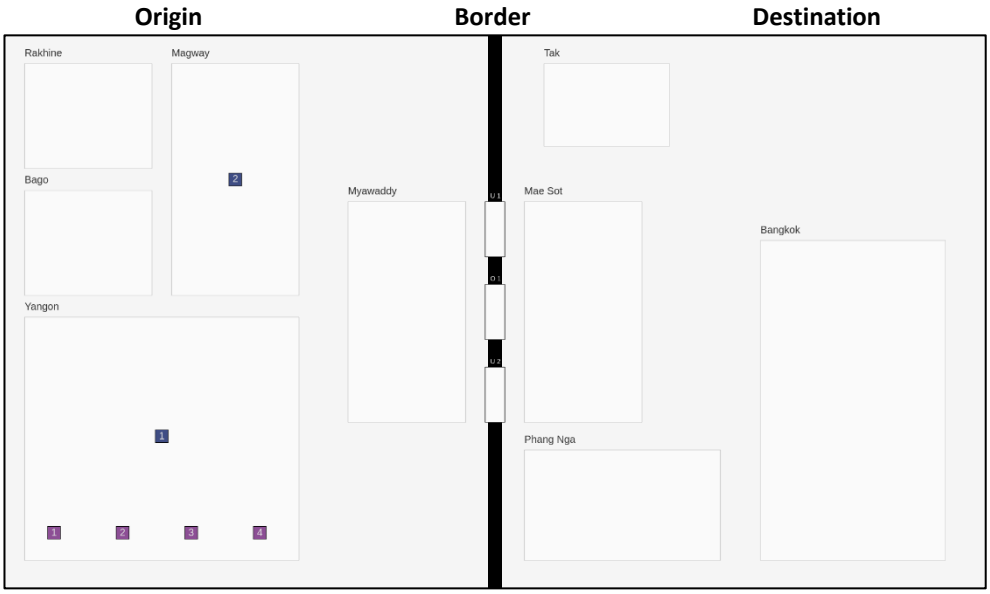


Figure 2. Environment without agents

Environment areas, sub-areas, proto-agents:

1. *Origin Area* (left side of Figure 2) with **five sub-areas**:
    - Two equal-sized rural: **Rakhine** and **Bago**
    - Three varying-sized urban, some with proto-agents:
        - **Magway** with one passport office ■
        - **Yangon** with one passport office ■ and four recruitment agencies ■■■■
        - **Myawaddy** - origin side of the border crossings
2. *Destination Area* (right side of Figure 2) with **four sub-areas**:
    - One rural: **Tak**
    - Three varying-sized urban: **Mae Sot** (destination side of the border crossings), **Phang Nga**, and **Bangkok**
3. Border with **three border crossings**:
    - One legal crossing:
        - **Official** – official immigration checkpoint
    - Two illegal crossings:
        - **Unofficial 1** – crossing without a Smuggler
        - **Unofficial 2** – crossing with a Smuggler

Corresponding author: alys.mcalpine@lshtm.ac.uk

Figure 3 presents the model environment, but this time populated with the agents in their initialised locations (Initialisation described in Section A.7.15).

Note that when migrants move between locations or are connected to intermediaries during waiting stages (i.e., recruiters, smugglers, or employers) then the colour of the line showing the migrant's movement or connection represents which migration state they are in (Figure 3, middle and bottom images).

Corresponding author: alys.mcalpine@lshtm.ac.uk

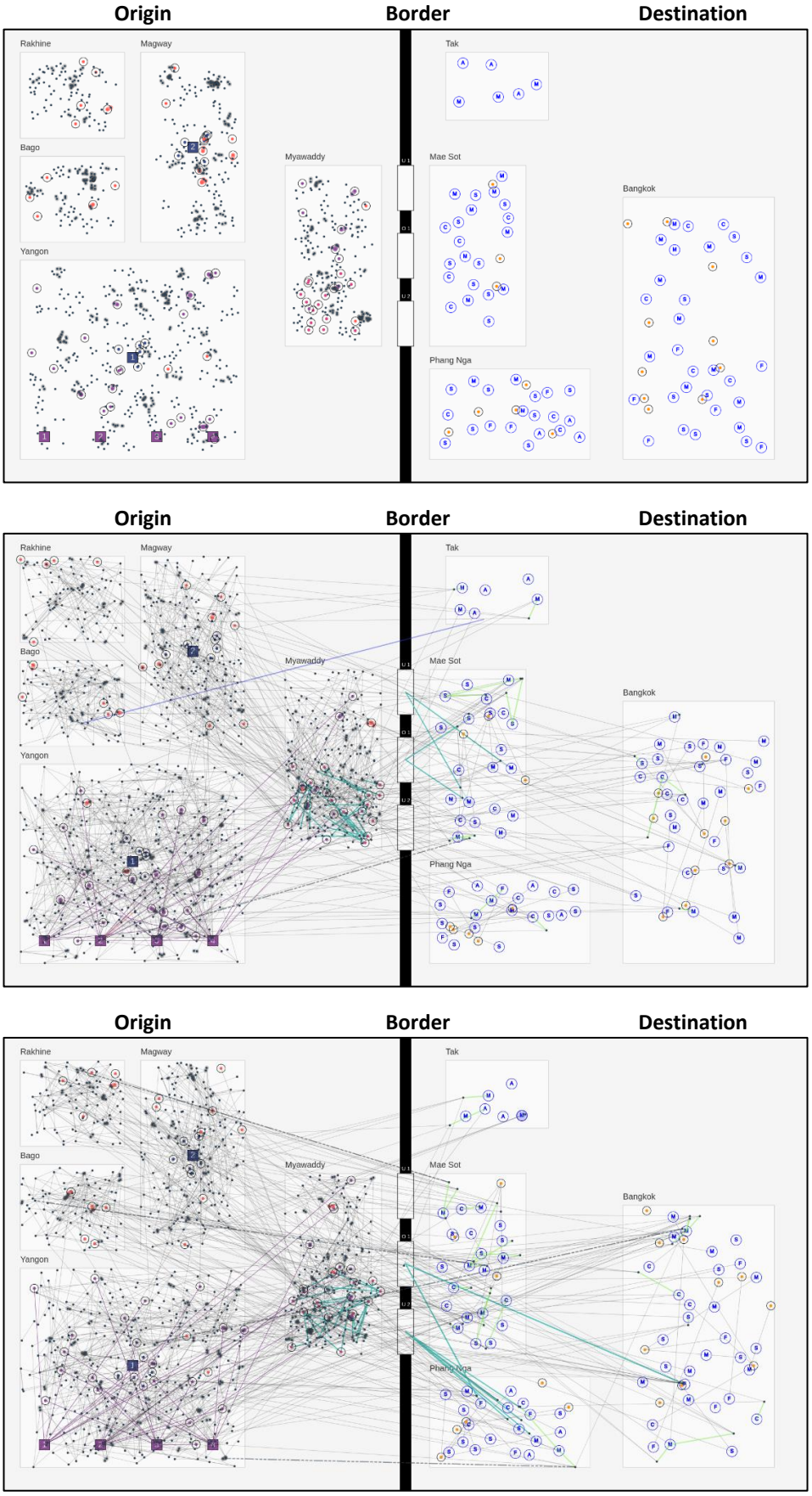


Figure 3. Environment with agents

Corresponding author: alys.mcalpine@lshtm.ac.uk

Model attributes – All model entities have properties (i.e., state variables) and actions (i.e., behaviours, decisions, state changes). Figure 4 presents a Unified Modelling Language (UML)[2] diagram of the MyTh MaP-IN model structure: the entities, properties, and actions (or 'methods'). One important feature of the model structure is the modularity between an instance of a *Migrant* that contains zero to many instance(s) of a *Migration* that each have a respective *plan*. The separation of a *Migration* and its *plan* helps distinguish a *Migrant's* intentions from the actual migration experience, but the use of similar properties allows for comparison between the two (e.g., planned documentation vs. actual documentation). The UML diagram is not exhaustive of every property or action, but covers most of them and all that are needed to understand the model process.

[2] UML is a standard graphical visualization for software development that is independent from any specific programming language or computer platform. Complex system simulations built using object oriented (OO) programming can be easily presented in the UML class diagram format, which includes relationships between classes such as *association* and *inheritance*). The format is intuitive and has a relatively low technical barrier (compared to writing code) and thus can be easily implemented and comprehended by a range of modellers. UML diagrams are a useful tool to summarise an ABM and it is argued that it can encourage greater focus on the modelling before the coding, yet it is still rarely included in ABM documentation (14).

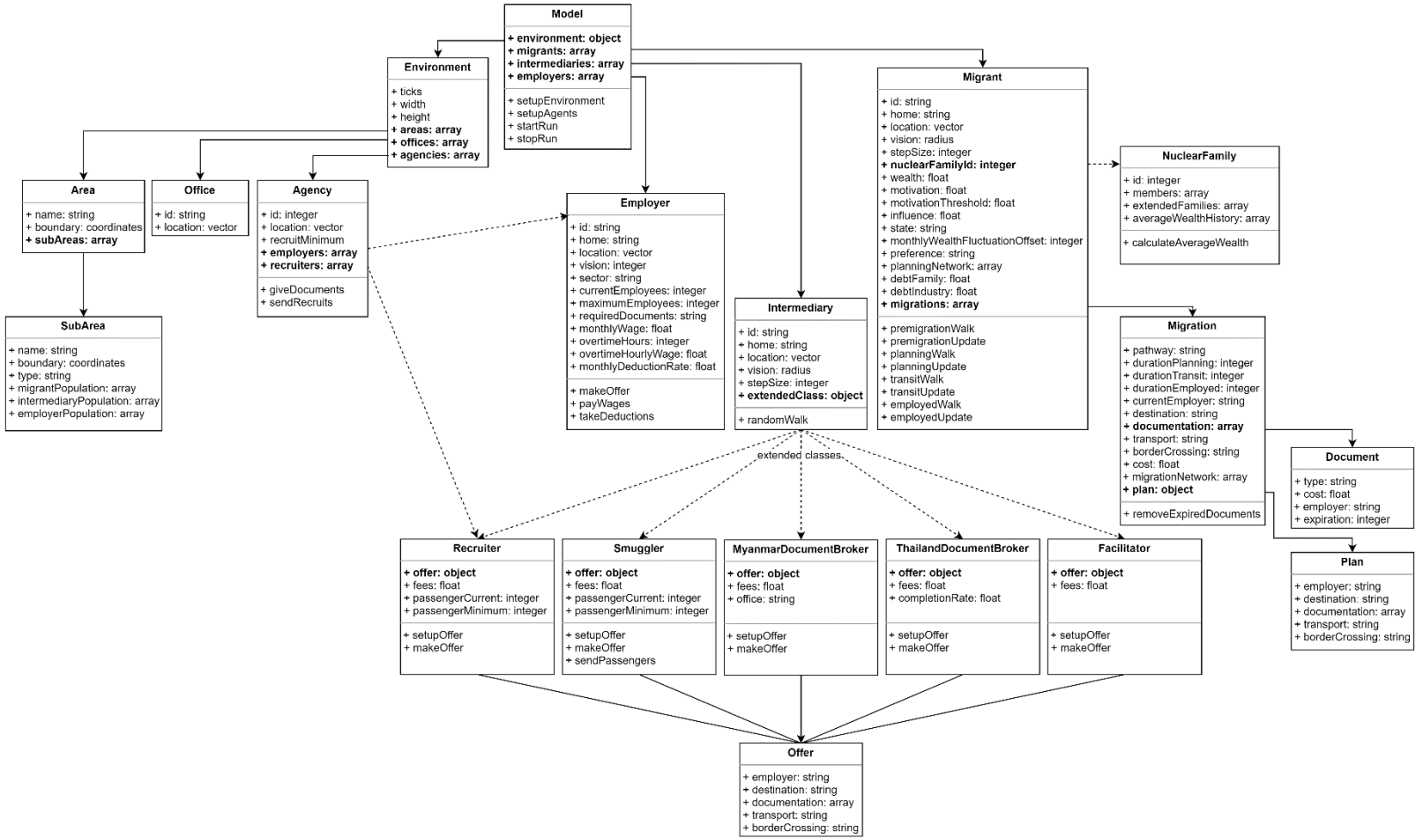


Figure 4. MyTh MaP-IN UML diagram

Model attributes (continued) – Table 2 lists the agent properties**,** their data structure, possible value, initialised value, and static or dynamic nature.

Table 2. Agent properties

	property	data type[1]	possible value	Initialised value	
All Classes	id	string	unique character/number string	**Migrant**: m0 . . .mN, **Intermediary**: i0 . . .iN, **Employer**: e0 . . .eN	S
	home	string	one of origin or destination sub-area	randomly allocated to match predetermined distributions from config file	S
	location	vector	x, y	randomly located within **home** sub-area. Two **agent class** conditions: **Employers** cannot overlap with each other; **Myanmar-Doc-Brokers** stay within a radius around passport offices.	D
	vision (and expanded vision)	radius	node diameter*X (and node diameter*X)	fixed radius around agent node (location specific)	S
	stepSize	integer	?	depends on agent class/state – move to each agent section below?	S
Migrant	nuclearFamilyId	integer	1+	randomly assigned and each id can be assigned to 1-5 Migrants	S
	extendedFamilies	array	0-2 nuclear family ids	1-3 nuclear family ids in same **home** area are randomly put into an extended family grouping	S
	wealth	float	constrained to 0-1 at end of every time-step	random within **home** specific ranges: rural (0 - 0.03), urban (0.015 - 0.045) (15)	D
	motivation	float	0 - 0.99	random between 0 - 0.35	D
	motivationThreshold	float	0.7 - 1	random between 0.7 - 1	S
	influence	float	0-1	random between 0 - 1	D
	state	string	'pre-migration', 'planning', 'transit', 'employed'	pre-migration	D
	monthlyWealthFluctuationOffset	integer	1-30	random between 1-30	S
	preference	string	one of eight preference types	randomly assigned (See additional description of **Preference** property and distibutions on next page.)	S
	planningNetwork	array	id(s) of Migrants and Intermediaries	empty	D
	debtFamily	float	0+ (no max)	0	D
	debtIndustry	float	0+ (no max)	0	D
	migrations	array	**Migration** instance(s)	empty (See **Migration** class below.)	D
Migration	durationPlanning	integer	0+	0	D
	durationTransit	integer	0+	0	D
	durationEmployed	integer	0+	0	D
	migrationNetwork	array	id(s) of Migrants, Intermediaries, and Employers	empty	D
	destination	string	one of destination sub-areas	empty	D

	borderCrossing	string	'official', 'unofficial1', 'unofficial2'	empty	D
	currentEmployer	string	employer id	empty	D
	cost	float	0+ (no max)	0	D
	plan	object	**Plan** instance	empty (See **Plan** class below.)	D
	documentation	array	**Document** instance(s)	empty (See **Document** class below.)	D
Plan	employer	string	employer id	empty	D
Plan	destination	string	one of destination sub-areas	empty	D
Plan	documentation	array	'border pass', 'work permit', 'passport', 'none'	empty	D
Plan	transport	string	smuggler's id, recruiter id, migrant id	empty	D
Plan	borderCrossing	string	'official', 'unofficial1', 'unofficial2'	empty	D
Document	type	string	'border pass', 'work permit', 'passport'	context specific generation based off interactions	S
Document	cost	float	.001 - .025 (100 – 2,500 THB)	assigned based on **type**: border pass = .001, work permit = .018, passport in Myanmar = .02, work permit in Thailand = .025, temporary passport in Thailand: 0.01	S
Document	expiration	integer	7 - 1825	assigned based on **type**: **border pass =** random between 7-1825**, work permit =** 730, **passport =** 1825, **temporary passport** = 730	S
Document	employer	string	employer id	empty	S
Agency	id	integer	1, 2, 3, 4	four agencies are initialised with unique 1-4 ids	S
Agency	employers	array	employer id(s)	randomly assign 5 unique Employers that have requiredDocumentation = 'work permit'	S
Agency	recruiters	array	recruiter id(s)	randomly assigned, at least one Recruiter in Yangon and one in Myawaddy per agency	S
Agency	recruitMinimum (per employer)	integer	3	**Recruiter** only: 3 for each employer in roster	S
Intermediary[2]	extended class	string	one of the five Intermediary types	randomly allocated to match predetermined distributions	S
Intermediary[2]	links	array	id(s) of Intermediaries and Employers	randomly created based on predetermined link probabilities	S
Intermediary[2]	fees	float	0.005 - 0.30 (500-30,000 THB)	randomly assigned within **extended class** ranges: **Recruiter** (0.05-0.30); **Facilitator** (0.02-0.15); **Smuggler** (0.05-0.10); **Myanmar-Doc-Broker** (0.02-0.04); **Thai-Doc-Broker** (0.04-0.10)	S
Intermediary[2]	agency	integer	1, 2, 3, 4	randomly assigned to **Recruiters** only	S
Intermediary[2]	passengerCurrent	integer	0+	**Smuggler** only: 0	D
Intermediary[2]	completionRate	float	.5-1	**Thai-Doc-Broker** only: randomly assigned	S

	passengerMinimum	integer	4-6	**Smuggler** only: randomly assigned between 4-6	S
	offer	object	**Offer** instance	empty (See **Offer** class below.)	-
Offer	employer	string	employer id	See Section A.7.9 for a description of **offer properties** for each **Intermediary extended class.** Offers contain a combination of the five offer properties listed here. The offer property values are assigned at initialisation unless described otherwise. Whether the properties are static, or dynamic depends partly on the **extended class**.	
	destination	string	one of four destination sub-areas		
	documentation	array	'border pass', 'work permit', 'passport', 'none'		
	transport	string	smuggler's id, recruiter id, migrant id		
	borderCrossing	string	'official', 'unofficial1', 'unofficial2'		
Employer	sector	string	one of five sectors	randomly allocated to match predetermined distributions	S
	currentEmployees	integer	0+	0	D
	maximumEmployees	integer	0+	by **sector**: **Agriculture** & **Services** (15); **Manufacturing** (100)**; Construction** (50); **Fishing** (30)	S
	requiredDocuments	string	'passport', 'work permit' with employer id, 'none'	by **sector**: **Agriculture** & **Services:** 'none required'; **Manufacturing, Fishing,** & **Construction:** random assigned 25% 'passport', 25% 'work permit' with employer's id', 50% 'none required'	S
	monthlyWage	float	0.0-.10 (0 – 10,000 THB)	randomly assigned within **sector** ranges: **Agriculture** & **Services** (.0-.08); **Manufacturing, Fishing,** & **Construction** (.0-.10)	S
	overtimeHours	integer	0-320	random between 0-320	S
	overtimeHourlyWage	float	0.000-0.004 (0-400 THB)	random between 0.000-0.004	S
	monthlyDeductionRate	float	0-0.5	random between 0-0.5	S
	links	array	id(s) of Thai-Document-Brokers	randomly allocated to match predetermined distributions	S

[1] Data structure key: integer = integer variable; float = real variable; string = categorical variable; array = list; object = model entity with its own set of properties with their own data structures

[2] For succinctness, all possible Intermediary properties are listed together, but the UML diagram depicts how each Intermediary extended class (e.g., Recruiter*)* has a unique set of properties.

Model attributes (continued) – This section provides additional details on select model attributes described in Table 2, including: currency, wealth, and migration preferences.

Currency: All the financial attributes of the model (e.g., wealth, fees, wages) represent Thai Baht (THB) currencies and are formalised as a float (i.e., a decimal). Financial attributes, as well as most other model attributes, adhere to a 0-1 range (i.e., normalised) for ease of interpretation and to allow convenient mapping to other ranges. The value range for financial attributes are informed by empirical data. Any empirical values that are stated in Myanmar Kyat (MMK) currency (e.g., pre-migration wealth) have been converted into THB using a 2019 exchange rate[3].

Currency translation examples (THB multiplied by 10^{-5} = empirical currency):

- 0.00001 = 1 THB (equivalent to approximately 47 MMK or $0.03 USD)
- 0.0033 = 330 THB (legal minimum daily wage in Thailand)
- 0.5 = 50,000 THB (approximate 6-month legal minimum wage)
- 1.0 = 100,000 THB (equivalent to approximately 4,723,580 MMK or $3,080.92 USD)

Wealth: Migrant wealth is a dynamic property. At the end of every time-step, wealth is constrained to 0 - 1, but during the time-step wealth might exceed these bounds temporarily depending on interactions or behaviours.

Preference: A Migrant agent has a migration 'preference' that influences their decision-making (Table 3). More research is needed to inform more sophisticated cognitive models of how preferences may interact, change over time, adapt to different contexts, but preferences in this model represent heterogeneous individual migration decision-making.

[3] Currency conversions were calculate using the Oanda currency converter for 1 January 2019, the year of data collection for this study. (www1.oanda.com/currency/converter/)

Table 3. Migrant preferences

Migrant preferences (in model)	Baseline distributions	CHIME study (16) and MMSNA study (17) findings
1. **Social** – community at destination: **destination** population has highest number of *Migrant* agents from **home**	**15%**	Friends at destination (30%)
2. **Family** – vetted pathways by family: **offer** from a family member	**15%**	Family/relatives at destination (16%)
3. **Intermediary –** wanting help/services: **offer** from *any* intermediary	**15%**	Availability of brokers/recruiters able to arrange migration (25%)
4. **Work** – plan for employer: **offer** includes eployer	**15%**	Confidence in finding employment at destination (12%), Work arranged prior to migration (7%)
5. **Sector – '**comfortable'/indoor work: **sector** = manufacturing OR services	**15%**	-Not included in CHIME- Came up as a very common theme in the MMSNA qualitative findings.
6. **Wage –** 'high' wage: **monthlyWage** ≥ .09 (i.e., 9,000 THB for 1-months work)	**10%**	Highest potential income option (7%)
7. **Fees –** 'cheapest' pathway: lowest total **fees**	**5%**	Low cost of migrating to destination. (2%)
8. **Proximity –** near home/'easy' to get to: **destination** closest to **home**	**5%**	Proximity of destination to home. (1%)
9. **Legal –** documented migration: **documentation** includes 'passport' **or** 'work permit'	**5%**	-Not included in CHIME- Came up as a common theme in the MMSNA qualitative findings.

Exogenous factors. Some of the model attributes and drivers are initialised at set values and are thus exogenous to the model. For example, the time it takes to process a passport and/or work permit, the distance between environment areas and time it takes to traverse them the daily cost of transit, debt interest rates, and debt deduction rates. These exogenous factors are described as global parameters in Section A.7.17.

Temporality – The *time-steps* (i.e., 'ticks') in the model represent days. The model *time-horizon* (i.e., model 'run' length) is 1,825 *time-steps* (5-years). The model run 'stops' when the completed time-steps reach the time-horizon. The 5-year time-horizon was chosen for a few reasons:

1. MyTh MaP-IN is informed by empirical data that was collected in 2019 from individuals that migrated to Thailand within the past 5-years (to minimise recall bias). This model is describing those migrations that took place between 2014-2019.
2. Additionally, beyond 5-years, most individuals will go through some significant life events (e.g., get married, have a baby, age out of work) that can alter their migration decision-making. A longer migrant life course approach is not central to the research questions and thus outside the scope of this ABM.
3. Finally, and practically, a 5-year time-horizon was achievable within the computational power available for this research. However, 5-year runs still allowed for the possibility of 'repeat' migrations in a single run (i.e., seeing how a Migrant might adapt their behaviours across migrations) given that the average migration from Myanmar to Thailand lasts between 2-3 years (18).

A.7.3 Process overview

MyTh MaP-IN consists of four sub-model processes. *Migrant* agents sequentially navigate through the sub-model processes to achieve two overall goals: 1) migrate to a chosen destination; and 2) be employed. A *Migrant* must first decide to migrate before they start forming plans to migrate. Planning and executing a migration involves a series of decisions, but also interactions with other *Migrant*, *Intermediary*, and, if they arrive at destination, *Employer* agents. See Figure 5 for a high-level conceptual framework of the overall model from the perspective of a *Migrant*. The actions that a Migrant takes to both develop and execute migration, respectively, may occur in stages over multiple sub-models. The black boxes in Figure 5 note all the possible sub-models that include any possible steps in these processes, the grey boxes summarise the step in the migration process, and the white boxes give examples of the types of agent behaviours in that migration step.

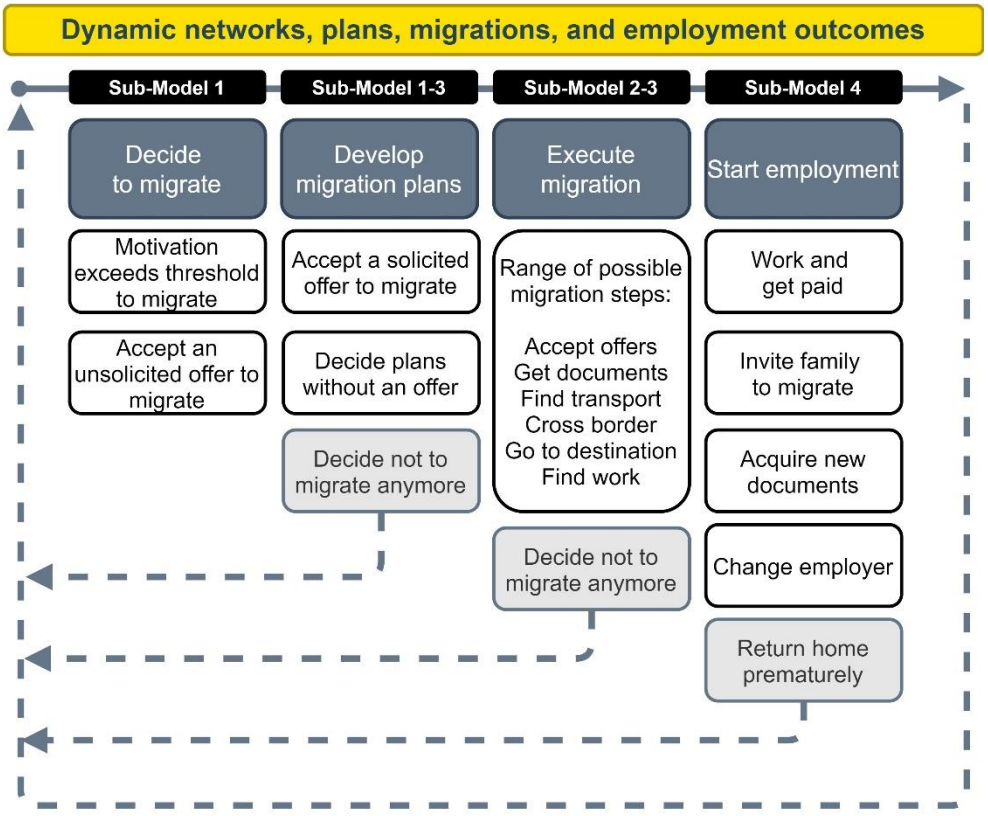


Figure 5. High-level conceptual model

The conceptual framework in Figure 5 guided the development of the sub-model rules and schedule. Figure 6 is a schematic that details *Migrant* agents' behaviours, decisions, and interactions. Section A.7.17 presents each sub-model and its respective rules, but Figure 6 has been included here to illustrate the translation of the high-level conceptual model into computational processes and rules.

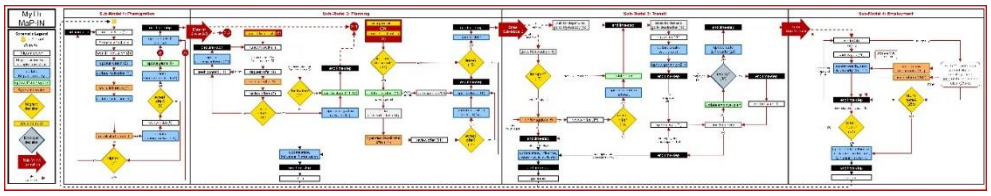


Figure 6. MyTh MaP-IN model schematic

A.7.4 Theoretical and empirical background

Massey and his contemporaries, Caroline Brettell and James Hollifield, suggest that interdisciplinary migration research creates an opportunity to use conceptual tools at different levels of analysis (e.g., micro-meso-macro) – a suggestion that is highly compatible to a complex realist approach (19, 20). In the aim of producing a multi-level model that captures some of the complexity of the Myanmar-Thailand migration corridor, this model is informed by a complimentary blend of theory and empirical evidence addressing the macro, meso and micro level entities, rules, and interactions.

The information and data that inform the MyTh MaP-IN model include:

- multi-level migration domain knowledge and theory (A.7.4a);
- published research on Myanmar-Thailand migration (A.7.4b); and
- empirical mixed-methods social network analysis (MMSNA) using data collected to inform the MyTh MaP-IN ABM (A.7.4c).

A.7.4a Multi-level migration theories

Figure 7, repeated below, summarises the **multi-level migration system theoretical framework** that informed the MyTH MaP-IN ABM. The framework depicts multiple levels of migration theory (micro-meso-macro) and an arrow representing inter-level interactions and feedbacks across the levels which make the content of each level change and adapt over time.

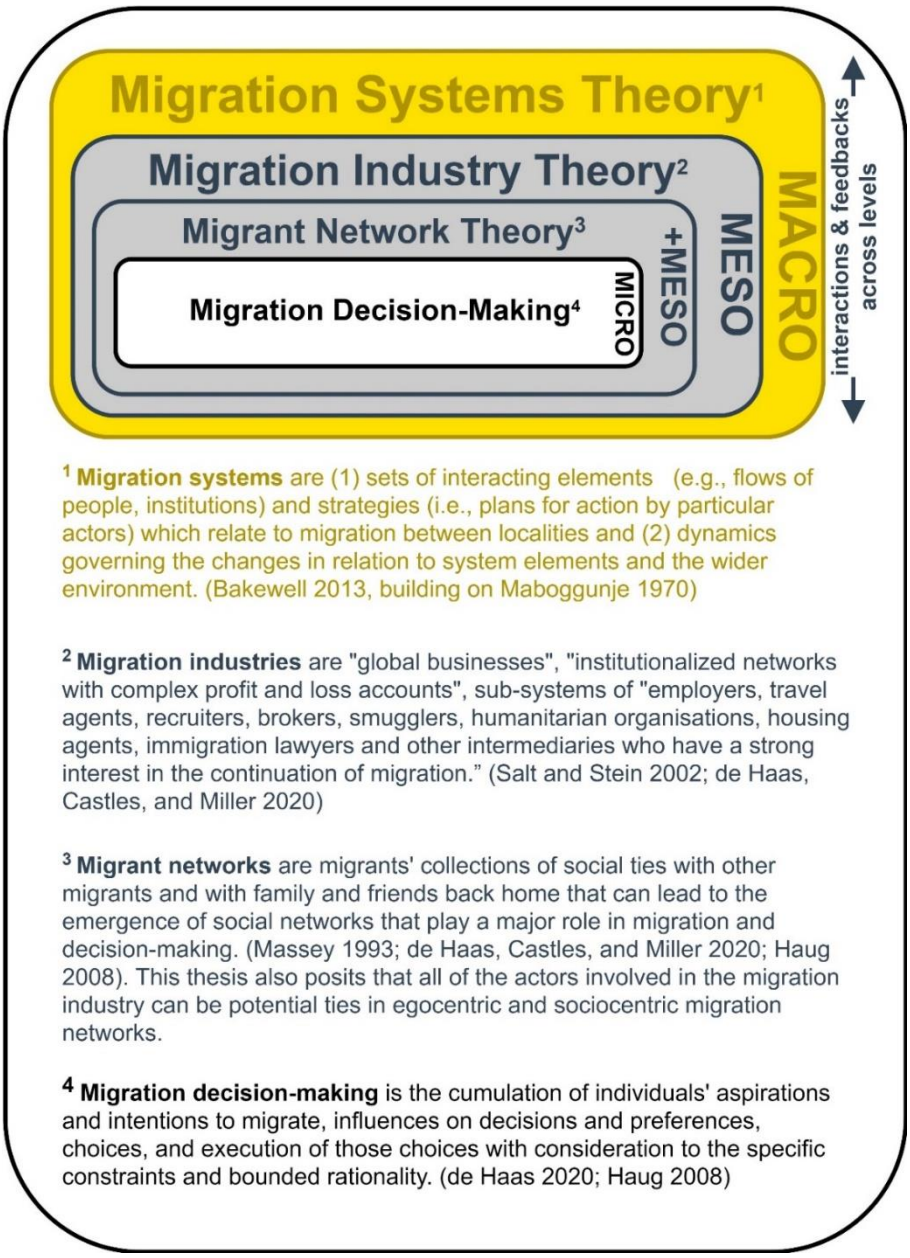


Figure 7. Multi-level migration system theoretical framework

Macro theory – informed choice of method and model entities

Senior Migration and Development Lecturer Oliver Bakewell, proposes a reformulated migration system theory (21) building on Mabogunje's similar work in 1970 (22). Bakewell defines a migration system as one that has:

> "(1) a set of interacting elements—including flows of people, ideas and goods, institutions . . . and strategies as in plans for action by particular actors—which relate to the migration between localities; and
>
> (2) dynamics governing the way in which the elements change in relation to changes in both these system elements (feedback mechanisms) and in the wider environment." (21, p. 310)

This theory supports the case for using complex systems methodologies that can feasibly explore system interactions and dynamics. Bakewell's definition suggests possible system features ('interacting elements', 'strategies', 'dynamics', 'feedbacks', 'environment') to incorporate into future conceptual or empirical work that addresses migration systems. This theory also guided the conceptual framework and empirical data collection for this ABM to ensure we addressed the "interacting elements" (e.g., people moving between environments, financial transactions, information exchanges) and the "dynamics governing" the processes and interactions within the system and impacting system elements.

Meso level theory – informed agent-agent and -environment interactions

Renowned migration scholars, Hein de Haas, Stephen Castles, and Mark Miller, state that a 'migration industry' can consist of, "employers, travel agents, recruiters, brokers, smugglers, humanitarian organisations, housing agents, immigration lawyers and other intermediaries who have a strong interest in the continuation of migration." (23, p. 66) John Salt and Jeremy Stein describe migration as, "a global business which has both legitimate and illegitimate sides . . . a system of institutionalised networks with complex profit and loss." (24, p. 22)

Bakewell, Castles, and Salt and Stein's complimentary theories informed our thinking of migration as a 'system of systems'. For example, a global system

of entities and flows that encompasses smaller finite sub-systems that sustain the dynamics and trends at all levels, such as industrial sectors that systematically recruit foreign workforces or social networks that sustain flows in specific corridors.

De Haas, Castles and Miller also explain that migrants "create and maintain social ties with other migrants and with family and friends back home . . .this can lead to the emergence of social networks (meso level structures)." (23, p. 65) Sonja Haug's work adds to the discussion on migration networks, she explains, "theoretical models and fragments of empirical evidence in several fields, show that migration networks play a major role in migration [and decision-making]." (25)

Castles suggests that migration theory and methods should be "able to incorporate both structure [macro-social] and agency [micro-social]." (26) That is, to address the larger 'system', such as geographies of migration or international immigration policy, while also acknowledging individual acts of agency, such as migration decision-making or work preference. Meso-level theories, such as migration industry theory and migration network theory, provide frameworks to consider potential 'touchpoints' between structure and agency. For example, social networks that emerge from individual migration choices and in turn establish macro level migration corridors. These corridors trends often influence immigration policy that then feeds back into the networks of decision-makers. The migration system encompasses individual actions and structural forces, but also the emergent properties of meso-level sub-systems and networks. To this point, we have considered the social and intermediary networks at the meso-level of the Migration-Thailand migration system.

Intermediaries (e.g., brokers, recruiters, 'middlemen') are a key group of actors that form specific migration industries within the system. An emerging body of research on migration intermediaries (7), highlights the range of roles they execute in the migration system and the way they are embedded within most migration processes. Dovelyn Agunias, an expert on migration mediation in many contexts, explains,

> By providing information and extending critical services in many stages of migration . . . legitimate intermediaries build migrants' capabilities and expand their range of choice. In the best of cases, intermediaries allow migrants the opportunity to move and pursue a life of meaning — the very essence of human development. . . . However, the services intermediaries provide come at a cost. It is difficult to draw a clear line between a reasonable fee for valuable services and exploitative charges or practices, or between exploitation and criminal abuse. (Agunias, 2009: 2) (27, p. 2)

Social networks are also a key meso-level sub-system that play a direct role in facilitating migration process. To date, the majority of research on migration networks has focused on these social networks (i.e., social groups of migrants facilitating flows) and some research, but minimal theoretical work, on intermediary networks, such as smugglers (28), and even less on the interaction or overlap of these social and intermediary networks (or 'industries'). The empirical data collection and analysis probed at these different actor groups and how these actors' relationships and interactions formed mixed intermediary and social networks at the meso-level of the migration system.

Micro level theory – informed agent behaviours, decisions, and processes

A single theory would struggle to explain all possible micro-behaviours exhibited by actors in a migration system. The micro-level of this multi-level theoretical framework focuses on migration decision-making as a key micro-influence on individual migration processes, the empirical focus of this research. Individual migrations are often conceptualised as trajectories (or 'pathways'). Stefanie Kley, sociologist and economist, adapted the Rubicon model of 'action phases' to the behavioural stages of migration (Figure 8) (29). Kley's model depicts four migration stages isolated by decision or action points. The stages include considering ('pre-decisional'), planning ('pre-actional'), and realizing ('actional') migration, and living at destination ('post-actional'). Zimmerman, Kiss, and Hossain, also consider migration 'stages' as a way to conceptualise the typical actions, opportunities, or vulnerabilities at various points in migration (30). Framing migration 'pathways' by stages offers one way to explore and organise the

range of decision-making and decision-making consequences that take place across the full trajectory of a migration. The MyTh MaP-IN sub-model represent the different migration stages discussed in the literature and incorporates specific opportunities, interactions, and decisions that are typical to specific locations and/or stages of a migration 'pathway'.

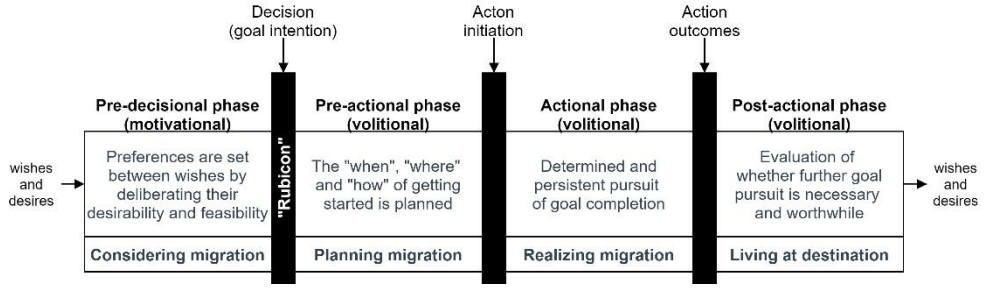


Figure 8. Kley's Rubicon model of planned action for migration (29)

Hein de Haas argues that "the main conceptual problem of conventional theoretical accounts of migration remains their inability to meaningfully conceptualise how individual migrants and groups of migrants exert agency within broader structural constraints."(31, p. 14) De Haas offers a theory to bridge the agency versus structure debate (micro vs. macro) with key relevance to migration decision-making (ibid). De Hass's 'aspiration-capabilities framework' conceptualises migration as, "a function of people's capabilities and aspirations to migrate within given sets of perceived geographical opportunity structures." (31, p. 2) That is, migrants' decisions to act, regardless of the motivation to migrate, are restricted by what is feasible given the broader meso- and macro- realities. Informed by de Haas's framework, the MyTh MaP-IN model formalises migrants' aspirations (to migrate, to find work, to satisfy individual preferences) within a system of opportunities, constraints, barriers, and possible failures (or drop outs) and the decisions to migrate being a function of both these agencies and capabilities (23). Not excluding that migrants, at times, can have the agency to defy structural constraints (e.g., poverty, oppression, migration restrictions) (31).

There is not a singular theory for migration decision-making, but the literature provides some general insights on migration decision-making that

have informed some of the rules in this model, in addition to the Aspirations-Capabilities Framework. These individual decision models are situated within and interact with the larger networks, industries, and migration system, these include the following migrant decision-making assumptions:

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

- economic incentives explain some but not all motivations to migrate (25);
- the decision to migrate is often a household, not individual, decision (23);
- migration decisions are made under a range of uncertainties, with imperfect and incomplete information (32);
- migration is a 'complex choice' with multiple objects and subjects of decision making at different stages (33); and
- the decision to migrate irregularly is often a means to circumvent unfavourable state systems, but also an emergent property of entrepreneurial initiatives within migrant networks (34).

The MyTh MaP-IN model builds on a strong body of interdisciplinary and multi-level migration theory. The model structure and global parameters formalise the geographical corridor and immigration policies that dynamically generate Myanmar-Thailand migration flows, as well as the industries and mixed social and intermediary networks that influence and facilitate migration pathways in the system. The actors within these migration networks execute their agency in the way they interact and make decisions across the stages of their migration process. The specifics of the entities and rules that govern this multi-level model are informed by a body of empirical research in the Myanmar-Thailand corridor.

A.7.4b Published research on Myanmar-Thailand migration

MyTh MaP-IN references the findings from two recent empirical studies to inform some of the model rules:

- In 2017, **University of Sussex** researchers and the **International Organisation for Migration** (IOM) conducted a mixed-methods study, *Capitalising Human Mobility for Poverty Alleviation and Inclusive Development in Myanmar,* that collected data on Myanmar migration trends in a randomly sampled household survey (n = 3,116) and qualitative interviews (n=192). This study aimed to "to address the lack of research regarding migration and its impacts on development in Myanmar . . . to generate evidence on contemporary labour migration patterns and impacts at the individual, household and community levels." (16) Hereafter referred to as 'the CHIIME study'
- In 2020, the **Central Statistical Organization** (CSO), **United Nations Development Programme** (UNDP), and **World Bank** co-produced the *Myanmar Living Conditions Survey 2017: Socio-economic Report*, which presents the findings from a large-scale multi-topic nationally representative living conditions survey (n = 13,730). (15) Hereafter referred to as 'the MLC survey'.

A.7.4c Empirical research on Myanmar-Thailand migration

The primary evidence that inform the MyTh MaP-IN rules is the empirical analysis that A. McAlpine completed as part of her Doctoral degre. McAlpine conducted interviews with migrant workers in Thailand. These interviews included participatory egocentric network mapping, demographic and outcome survey questions, and in-depth qualitative probing. This data was analysed using a mixed-methods social network analysis (MMSNA) approach and the findings of this empirical analysis have been written up as a separate paper (17). Hereafter referred to as 'the MMSNA study'.

Empirical data – The empirical data for the MMSNA study was collected in 2019 in three data collection sites in Thailand: Phang Nga region, Tak region (including Mae Sot central); and Mahachai region (outside of Bangkok). The sample is Myanmar adults (18 years or older) that are living in Thailand and migrated to Thailand for work in the last 5 years. The total sample size was n=100 but only 81 of the interviews were used for the empirical analysis (4 interviews were excluded based on sampling criteria, 15 interviews were randomly partitioned for model rule validation – see Section A.7.20). The

dataset includes both quantitative and qualitative data that were collected during single interview sessions. The structured quantitative dataset includes egocentric network data (both egos and alters), demographic attributes of both egos and alters, and various work and migration outcomes. The qualitative dataset is made up of interview transcripts where migrants described their migration narratives in more detail including their relationships and exchanges with the alters in their migration networks. More details on the methods of data collection and analysis can be found in the MMSNA paper (17).

Data aggregation – The data is available at the individual and egocentric network level (i.e., migrant interviewees and the network of people they described as being involved in their migration).

Combining the model inputs

Figure 9 presents a high-level outline of how the published research and empirical analysis informed the different levels of the MyTh MaP-IN model. The multi-level migration theories (squares) and data sources (arrows) were triangulated in the model design process.

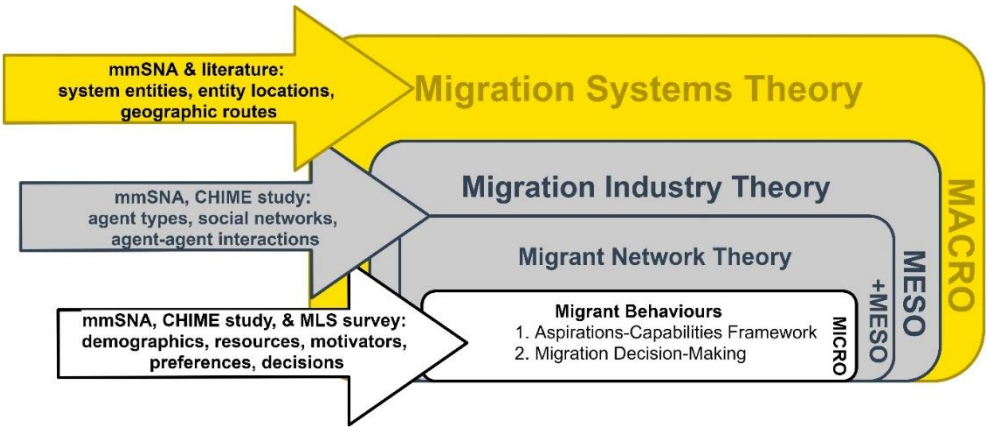


Figure 9. Theory and evidence informing the MyTh MaP-IN model

Model assumptions

A summary of some of the key assumptions that informed the model design are bulleted in thematic groupings.

Assumptions about pre-migration and the motivation to migrate

- All migrant agents have wealth that fluctuates over time on the assumption that all family members, regardless of working age, have household wealth allocated to their livelihood. Unemployment is not explicitly formalised but is one type of financial loss modelled as a simple 'financial shock' catch-all.
- On average, *pre-migration* wealth decreases over time due to possible financial shocks.
- Motivation to migrate is heterogeneous and is affected by social influences and relative (not absolute) nuclear family wealth.
    - Social influence from family members and returned migrants is double weighted.
    - Positive and negative influences that are the same relevant distance from an agent's current motivation have the same proportional effect on motivation.
    - Relative wealth influences all migrants' motivation uniformly.
    - The relative poorest and highest wealth brackets are less incentives to migrate compared to low-middle range family wealth categories.
    - All agents are aware of the wealth and influence of migrants in their home area and/or vision.
    - Social influence affects all agents' motivation, but wealth only affects agents with motivation below a certain value.
- Some agents have a migration threshold set so that they can never migrate based on the assumption that some population members would never migrate due to health or age.
- Agents with a certain level of motivation to migrate are more susceptible to accepting offers to migrate than individuals with relatively low motivation (compared to individual thresholds to migrate).

Assumptions about the Migrant decisions

- Migrants only receive social offers (i.e., not intermediary offers) to migrate from family members and are more likely to accept family offers than intermediaries offers at the 'decision to migrate' stage (i.e., before they are proactively looking for any plans).
- Migrants have individual preferences that guide their migration choices.

- Migrants without any plans to migrate will seek out advice or help from contacts they know or know of. Eventually, migrants that do not receive help will make independent migration decisions.
- Migration plans can be discontinued at any stage of migration.
- Destination plans affect migrants' documentation and transport decisions. Documentation decisions affect migrants' transportation decisions.
- If a migrant has accepted an offer from a Recruiter or already has a passport then they are less likely to decide to discontinue their migration after these offers or exchanges have taken place

Assumptions about Intermediaries

- Different types of intermediaries are in certain areas which influences which offers an individual might receive or have access to. Migrants know the location of smugglers in Myawaddy.
- Migrants that use Myanmar-Doc-Brokers or Recruiters are guaranteed to receive their documentation pre-migration.
- Not all intermediaries link equally to all other intermediaries and not all intermediary links are bidirectional.
- Smuggler and recruiter intermediaries work on 'economies of scale' which means they must meet minimum numbers of migrant customers to move a group of migrants onto the next stage of migration.

Assumptions about migrations and employment

- Migration pathways are established and sustained by migration networks, especially family inviting other family.
- All Migrants that decide to leave home are either able to cover the costs of migration from their individual wealth or are willing to execute migrations by taking on debt to social networks or to the migration industry (i.e., intermediaries, employers).
- Migrants can leave home without a full migration plan.
- Migration is pathway dependent, and decisions made in one time-step will increase or decrease the likelihood of future decision outcomes.
- Passport costs the same regardless of the passport office location.
- All Migrants can acquire a border pass if they pass through the official border crossing.
- Migration from the border area to destination is deterministic with no potential for death or failure.
- All migrants assess their situation after 6-months of working.
- All migrants have the same relative financial 'goal' that determines when they return home.

- If a migrant is still in debt to an employer or intermediary (i.e., debt to industry) they cannot go home.
- All employed migrants at destination without a work permit will try to get required documents if prompted with the decision to get new documents (different then 'interaction with broker', agents must be prompted to decide to accept).
- Migrant agents with lower precarity scores are more likely to invite their family member to migrate. All migrants that invite their family member to migrate and know there is vacancy at their employment will offer the employment to their family.
- All migrants that increase their wealth during a migration also have an increased influence on others to migrate.
- All migrants that decrease their wealth during a migration also intentionally 'forget' their planning network contacts to not recommend them to others or use them for future migrations.
- Migrants that are not achieving their financial 'goal' or satisfying their employment preference are more likely to attempt to change their employer.

Rational for decision-model choices. The behaviours and decisions that have been formalised in the Sub-Model rules have corresponding rationale listed in the Sub-Model process descriptions in Section A.7.17 Tables.

A.7.5 Individual decision-making

Subjects and objects of decision-making – Decision-making is modelled on an individual level. *Migrant* agents are the most frequent subject of decisions. A *Migrant* makes multiple decisions in one migration and the range of possible objects include whether to: migrate; accept an offer; acquire documents before departure; use transport services; to pursue an employment options; invite family; acquire new documents at destination; and/or return home or keep working. An *Employer* is the subject of the decision of whether to make an employment offer to a *Migrant*. Figure 10 gives a condensed summary of the decision points across the four sub-models.

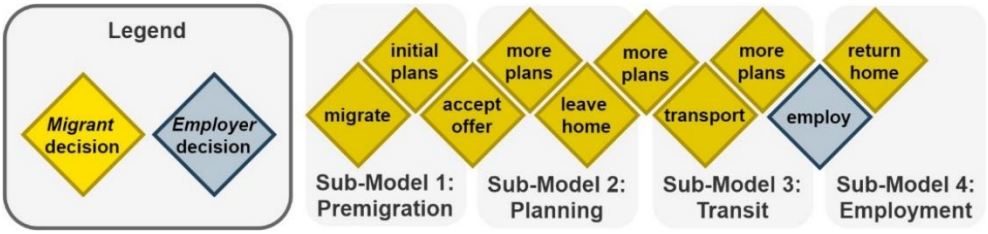


Figure 10. Decision-models across sub-models

Decision-making rationality and success criteria – A *Migrant's* overarching 'objective' that guides their sequential decision-making objectives is an explicit goal of migrating to a destination and being employed there. A *Migrant* also has an objective to meet their migration **preference** and to improve their financial situation (e.g., increase **wealth**). In the model, 'success' is a measure of whether they achieved their primary aim (migration and work), but also whether they increased their **wealth**, met their **preference**, and their level of **precarity** at destination (the latter is not an 'objective' of the Migrant agents but a 'success' criteria in the model).

Agent decisions – In Sub-Model 1, a Migrant agent decides to migrate by either accepting an **unsolicited offer** to migrate or by having 'enough' **motivation** (i.e., motivation $\geq$ motivationThreshold). A Migrant decides whether to accept an offer by comparing the **offer** properties to their migration preference, but also by having a **motivation** that is within a certain distance of their **motivation threshold**. A Migrant also makes other

decisions about their migration **plan** and which **offers** to accept again based on their **preference**, but also based on their networks and any **plan** properties that are already populated. The conditions, parameters, and in some cases, probabilities for all Migrant decision-models are detailed in their respective Sub-Model process (Section A.7.17). When an Employer receives a request from a *Migrant*, the *Employer* decides whether to make an **employment offer** based on their employee vacancy (i.e., currentEmployees < maximumEmployees) and whether the *Migrant's* **documentation** matches the *Employer's* **required documentation**.

Agent adaptation to changes in endogenous or exogenous state variables – In some cases, a *Migrant's* migration **preference** (e.g., a destination with a large **social** network, a more 'comfortable' indoor job site, such as a factory or hospitality venue) mean that their decision to accept **offers is** responsive to some of the dynamic endogenous state variables in the model (e.g., the total population of other migrants from their home area at the destination, vacancies at manufacturing or service *Employers*). A *Migrant's* decisions are also responsive to the emergent migration networks of their **family** and returnee *Migrants* in their **home** area.

Social norms and cultural values in decision-making – Neither social norms nor cultural values have been explicitly included in the decision-models. However, Sub-Model 1 includes a variable that represents social 'influence' that may increase or decrease a Migrant's motivation to migrate. This 'catch all' influence can be interpreted as a proxy for the range of social influences on the motivation and then decision to migrate.

Spatial aspects in decision-making – A *Migrant's* **home** may influence the **offer** they will accept if they have a **preference** to stay near their **home** (i.e., preference = proximity). Additionally, the sub-area a *Migrant* is in determines which type of *Intermediary* interactions are possible as not all types of *Intermediary* extended-classes are in all sub-areas. Lastly, the **destination** of family members and other Migrants from a Migrant's home area will also determine which offers a Migrant receives through their wider networks, and accepts (i.e., preference = social).

Temporal aspects in decision-making. If a *Migrant* in planning state has not accepted an offer for 30 time-steps, they are prompted to decide their destination or discontinue their migration. Temporal aspects are not conditions for the decision, only whether and when to make the decision.

Decision-making under uncertainty. The MyTh MaP-IN ABM does not formalise 'uncertainty' as an influence on decision-making explicitly although there is some uncertainty that is implicit in Migrant's decision-making processes. For example, Migrants accept 'offers' to populate their migration plans with a set of properties, but these plans are not always a **guarantee** of migration outcomes (e.g., a Migrant may not always get a job at the employer in their plans based on an offer they received from an Intermediary or family member). At some points in the model, Migrants use the offer of an '**employer'** as a condition that influences their likelihood to **accept an offer.** This implies that an offer including an employer is more preferential in some situations in part because the assumption is that having an employer offer/plan provides a degree of more certainty of employment at destination but overall, there will still always be the uncertainty described previously – i.e., that an employer plan might not actualise as employment – but this uncertainty is the same for all migrants and not explicitly formalised in the decision rules. Decision-making under uncertainty is an area for future work (See Section A.7.22), that requires more dedicated exploration of the various models of decision-making processes under uncertainty which is beyond the scope and data available in this research.

A.7.6 Learning

Individual learning. *Migrant* agents learn from their migration experiences. Before they return to pre-migration state, regardless of what stage of migration they are currently in, they update their **influence** (1) and **preference** (2). A *Migrant* returning from *Employed* state also updates their **planning network** (3) based on their migration outcomes. Change in **influence** and **planning network** affect how a *Migrant* influences others' migration decision. Changes in **preference** and **planning network** affect their own possible future migrations

Collective learning. There is not explicit *collective* learning in the model. However, over time, the cumulative effect of changes from *individual* learning affects the aggregate 'influences', but also changes in planning networks and preferences may influence the overall trends in migrant destination choices which for some migrants with a 'social' preference (i.e., the preference to go where others are) might indirectly present as collective learning if migrants are following emergent pathway trends based on individual learning.

A.7.7 Individual sensing

Individual sensing of endogenous and exogenous elements. Agents can sense some properties of other agents (endogenous elements) and spatial features of the model (exogenous elements) (Table 4).

Table 4. Endogenous and exogenous model elements

	Endogenous	**Exogenous**
Migrant	• all agents in their **vision** • **destination** of other **home** *Migrants* • **employment state** of **family** • **wealth** of other **home nuclear families** • *Migrants'* **migration** history	• **boundaries** of sub-areas • **locations** of *passport offices*, *agencies*, *border crossings* • **location** of their **employer plan**
Intermediary	• *Migrants* in their **vision**	• **boundaries** of sub-areas • *Myanmar-Doc-Brokers* sense **location** of *passport offices*
Employer	• N/A	• N/A

Individual sensing of other individuals' state variables – Agent 'sensing' of other agents' state variables depends on some spatial or social condition being met before the exchange of information is possible. When the condition is met the exchange is automatic. For example, two *Pre-migration-Migrants* located in each other's **vision** will automatically exchange **influence**. Agent sensing is never erroneous, that is, *Migrants* always sense accurate information about other *Migrants* and about spatial elements. For example, a *Migrant* agent senses their own **nuclear family's wealth** *and* all other **nuclear families' wealth** of their **home** area without modelling an explicit transfer of this information and the 'value' of the **wealth** properties they sense are always accurate.

Spatial scale of sensing – The spatial scale differs depending on the interaction taking place. For example, family members can interact across the full model space (i.e., it does not matter how far two family members are away from each other, they can still interact). Other *Migrant-Migrant* interactions or *Migrant-Intermediary*, *Migrant-Employer* interactions depend on spatial proximity which is defined in this model as '**vision'** which is a set diameter space around the agent node in the model. This visual field can be increased for some rules.

Mechanisms of obtaining information – Some exchange of information requires direct links or proximity (e.g., **influence**, **offer**) and these types of exchanges are explicitly modelled in the Sub-Model processes. Other information exchange is implicit, such as knowledge of home area wealth distribution or location of spatial features.

Costs of cognition or gathering information – There are two points in the model where there are explicitly executed but are indirect 'cost for cognition'. First, when a *Transit-Migrant* is trying to find a *Smuggler* **offer** in Myawaddy it increases their time in transit which incrementally increase their cost of migration since there is a 'daily' cost for being in transit. Second, when a *Transit* or *Employed-Migrant* is trying to find an Employer **offer** in destination there is an opportunity cost for the time-steps is takes them to find an *Employer* because this delays possible earnings.

A.7.8 Individual prediction

Type of data agents use to predict future conditions. A *Migrant* agent use the information they are given in the **offer** to predict their migration process and future employment. *Migrant* agents also use their sensing of their family and home community Migrant's location to predict their fellow Migrants at specific **destinations**. *Intermediary* and family *Employed-Migrant* agents use *Employer's* **vacancy** to predict if there will be employment for a *Migrant* once they arrive.

Type of behavioural models that agents use to estimate future conditions. In some cases, Migrants use a basic utility maximisation model to compare offers and choose one that has employment, highest ages, and, in some cases, closer spatial proximity to their home area.

Potential for erroneous predictions. Migrants' decisions and the implicit predictions they are making in these decisions (i.e., to have employment when they arrive, to arrive at a destination where family is, etc.) are based on the information they sense in the model or information that is communicated to them through interactions. Their sensing is not erroneous (i.e., they are sensing the 'correct' information about their environment, and they receive the 'correct' information the other Agent is communicating), but it is possible that a Migrant's outcome does not reflect the prediction they were making in their decision. For example, a Migrant might be given an employer offer by a family member but by the time they arrive there is no vacancy at that job site. The information was not erroneous ('wrong') but the prediction was incorrect as because of the dynamic nature of an Employer's vacancy.

A.7.9 Interaction

Direct and indirect agent interactions. Agent interactions are almost entirely direct. The exception is that some agents transfer indirect offers to a *Migrant* via their network **links**. Table 5 summarises the interactions, whether they are direct[D] or indirect[In], and changes to **properties.**

Table 5. Agent-Agent interactions by sub-models

	Agent-Agent interactions and **properties** affected
1: Pre-migration	• A *Migrant* can influence[D] a *Pre-migration-Migrant's* **motivation** to migrate. • A *Pre-migration-Migrant* can receive[D] and accept[D]/reject[D] unsolicited **offers** from a(n): **1)** *Facilitator;* ***2)*** *Employed-Migrant* (**family**); OR **3)** *Recruiter*. ▪ An unsolicited **offer** can also link[In] to another *Intermediary,* which presents the *Migrant* with the option of accepting[D] a **combined offer.**
2: Planning	**Sub-Model 2-A:** • A *Planning-Migrant* without an accepted **offer** can request[D] an **offer** from an agent in their **planning network**. ▪ If a **planning network** agent receives[D] a request they can respond[D] with a solicited **offer**. • A solicited **offer** can also link[In] to another *Intermediary,* which presents the *Migrant* with the option of accepting[D] a **combined offer.** **Sub-Model 2-B:** • A *Planning-Migrant* near a passport office can receive[D] and accept[D]/reject[D] an unsolicited **offer** from a *Myanmar-Doc-Broker.* ▪ An unsolicited **offer** from a *Myanmar-Doc-Broker* can also link[In] to a *Recruiter,* which presents the *Migrant* with the option of accepting[D] a **combined offer.**
3: Transit	• A *Transit-Migrant* that needs transport can request[D] an **offer** from a *Smuggler* in their **planning network** or within their **vision**. ▪ If a *Smuggler* receives[D] a request they can respond[D] with a solicited **offer**. • An *Employer* can receive[D] and accept[D]/reject[D] a request for an **employment offer**. ▪ A *Transit-Migrant* then accepts[D] that **employment offer**. • A *Transit-Migrant* pays[D] the **fees** to all *Intermediaries* once they arrive in **destination**.
4: Employment	• An *Employed-Migrant* can make an unsolicited **offer** to a *Pre-migration-Migrant* in their **family** (*Pre-migration-Migrant's* response[D] detailed in Sub-Model 1). • A *Thai-Doc-Broker* can receive[D] and accept[D]/reject[D] a request for a **documentation offer**. ▪ An *Employed-Migrant* can then accept[D] that **offer** from the *Thai-Doc-Broker*. • An *Employer* pays[D] an *Employed-Migrant* their **wages.** • An *Employed-Migrant* can pay[D] off their **debt** to their *Employer*.

Conditions for interactions. Interactions depend on either spatial proximity (i.e., within **vision**), social proximity (i.e., **nuclear/extended family** or **home**), or network links. Interactions are conditional on other factors, such as agent properties or, in the case of a *Migrant*, plan and migration properties. The conditions are detailed in Section A.7.17.

Communication in interactions. Offer transactions (e.g., requesting, making, receiving, accepting, rejecting, or combining offers) are the primary form of communication. Table 6 describes the information communicated in every possible offer, including combined offers through network links. Figure 11 is a simplified version of the UML diagram depicting how agent interactions and offers populate a Migrant's **migration** and **plan.**

Coordination networks. Relational links influence the offers a Migrant receives and offers they request. Some of the network links are imposed and others emerge during the model run.

Table 6. Offers and combined offers

DECISION-MAKER	PLAN property	all possible VALUES	populating plan without a *pre-migration* offer	populating plan with accepted offer					
				+ R	*+ MDB*	*+ S*	+ F	+EM	*+ TDB*
Migrant	employer	employer id	decide during planning, transit, or employment	✓	✖	✖	✓	✓	✖
	destination	'bangkok', 'phang nga', 'tak', 'mae sot'	decide during planning	✓	✖	✓	✓	✓	✖
	documentation	['border pass', 'work permit', 'passport', 'none']	decide during planning or employment	✓	✓	✓	✖	✖	✓
	transport	smuggler, recruiter, or migrant id	decide during planning or transit	✓	✖	✓	✖	✖	✖
	border crossing	'official', 'unofficial1, 'unofficial2'	decide during planning or transit	✓	✖	✓	✖	✖	✖
OFFERER	**OFFER property**	**offer possible VALUES**	**populating offer property**	**Base Offer Modifiers**					
Recruiter (R)	employer*	employer id	any from recruiter's agency's employer **roster**	✖	✖	✖	✖	✖	✖
	destination*	'bangkok' or 'phang nga'	always: employer's **home**						
	documentation	['work permit' and 'passport']	always: both **types** in combination						
	transport	recruiter id	always: recruiter's own **id**						
	border crossing	'official'	always: 'official'						
Myanmar-Doc-Broker (MDB)	employer	✖	-	✖	✖	✖	✖	✖	✖
	destination	✖	-						
	documentation	'passport'	always: 'passport'						
	transport	✖	-						
	border crossing	✖	-						
Smuggler (S)	employer	✖	-	✖	✖	✖	✖	✖	✖
	destination	'bangkok' or 'phang nga' or 'tak'	random: 'bangkok' (50%), 'phang nga' (30%), 'tak' (20%)						
	documentation	'none'	always: 'none'						
	transport	smuggler's id	always: smuggler's own **id**						
	border crossing	'unofficial2'	always: 'unofficial2'						
Facilitator (F)	employer	employer id	sometimes: from facilitator's **links** / otherwise: empty	R	F ✖	F ✖	✖	✖	✖
	destination	'bangkok' or 'phang nga' or 'tak' or 'mae sot'	employer's **home** / random: 25% chance each destination	R	F	S			
	documentation	✖	-	R	MDB	S			
	transport	✖	-	R	✖	S			
	border crossing	✖	-	R	✖	S			
Employed-Migrant (EM)	employer*	employer id	sometimes: own **employer** IF vacancy / otherwise: empty	R	EM ✖	EM ✖	✖	✖	✖
	destination*	'bangkok' or 'phang nga' or 'tak' or 'mae sot'	always: current **destination**	R	EM	S			
	documentation	✖	-	R	MDB	S			
	transport	✖	-	R	✖	S			
	border crossing	✖	-	R	✖	S			
Thai-Doc-Broker (TDB)	employer	✖	-	✖	✖	✖	✖	✖	✖
	destination	✖	-						
	documentation	'work permit' and/or 'passport'	always: offer both **types** in combination or separate						
	transport	✖	-						
	border crossing	✖	-						

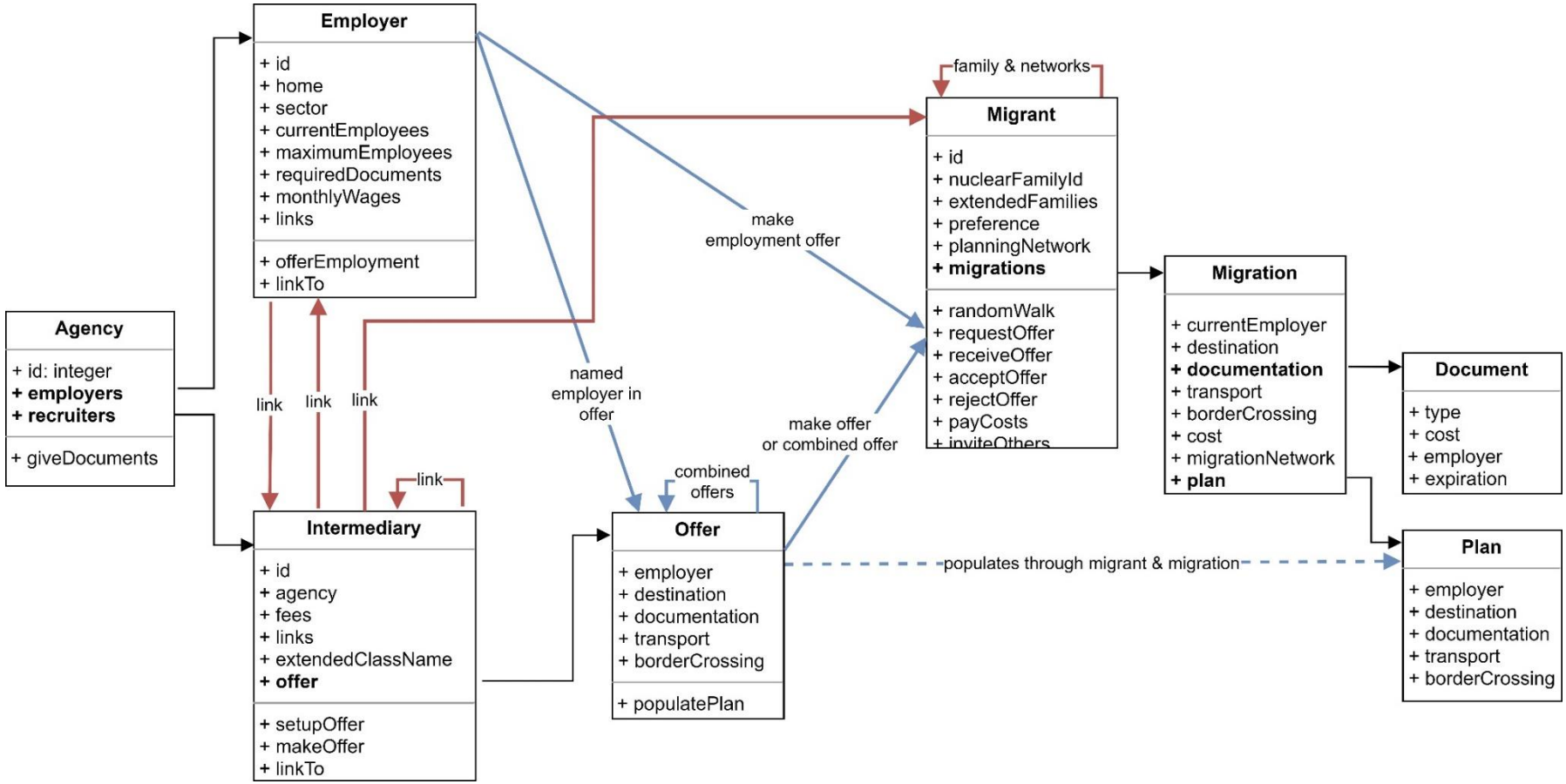


Figure 11. Simplified UML diagram specific to agent links and offers

A.7.10 Collectives

Agent aggregations. Agents are aggregated in family groups and networks via links. Some of the network links are imposed and others emerge during the model run (Table 7).

Table 7. Agent networks – imposed and emergent

Imposed network	Emergent network

• Nuclear and extended families
• *Intermediary* unidirectional links:
  ▪ *Facilitator – Recruiter*
  ▪ *Facilitator – Smuggler*
  ▪ *Myanmar-Doc-Broker – Recruiter*
• *Agency-Agent* links
  ▪ *Agency-Recruiter*
  ▪ *Agency-Employer*
• *Intermediary-Employer* unidirectional links:
  ▪ *Recruiter – Employer*
  ▪ *Facilitator – Employer*
  ▪ *Smuggler – Employer*
• *Employer-Intermediary* unidirectional links:
  ▪ *Employer – Thailand-Doc-Broker*
	Each *Migrant's* **planning network:**
	• *Migrant* bidirectional links
	• *Intermediary* bidirectional links, any *Intermediary* extended-class
	
	Each **migration network**:
	• *Migrant* bidirectional links
	• *Intermediary* bidirectional links, any *Intermediary* extended-class
	• *Employer* bidirectional links

Network and links' effect on Migrants:

- Nuclear and extended families affect wealth, influence, motivation, and offers received.
- *Intermediary-Intermediary* links form combined offers.
- *Agency-Employer* and *Agency-Recruiter* links determine employer offers from Recruiters.
- *Intermediary-Employer* links determine employer offers.
- *Employer- Thailand-Doc-Broker* links give access to new documentation at destination.
- A **planning network** informs which agents receive a Migrant's request.
- A **migration network** helps form a Migrant's plan and migration, but also is a group of links that a Migrant can share with other Migrants.

Collective representations. *Intermediary-Intermediary, Intermediary-Employer,* and *Employer-Intermediary* links are represented as straight lines between the agents in the model. Family aggregations are also represented as lines between *Migrant* agent nodes in the same family.

A.7.11 Heterogeneity

Heterogenous properties or behaviours. Most of the agent properties, apart from **vision** and **stepSize**, for all three agent classes are heterogenous and the ranges of possible values for each property is described in Table 2 (in section A.7.2 above).

Heterogeneous decision-making. *Migrants'* decision rules, some of the conditions for these rules, and the order of execution of these decisions are the same. However, *Migrants'* **networks** (that partly determine the **offers** they receive) and *Migrants'* migration **preferences** (a decision-making parameter) are heterogenous inputs to the decision process. Some *Migrants* have more decision points (e.g., decide destination, decide border crossing) if they have not accepted **offers** that include these **plan** properties. *Employers'* decision models for the employment offers are not heterogenous.

A.7.12 Stochasticity

Random or partly random processes in the model. Agents' initialised location, links, and many property values are assigned randomly, sometimes randomly within class, extended class, or sector. See Table 2 (in section A.7.2 above) for which properties are initialised randomly and how. *Migrant* and *Intermediary* agents execute random walks at different points in the sub-model processes. *Intermediary* and *Employer* links are also initialised randomly based on predetermined probabilities detailed in section 7.15. *Migrant* and *Employer* decision-making is probabilistic once the prior conditions for activating the decision process have been satisfied.

A.7.13 Observation

Data collected from the ABM – Data is logged every time-step and each 'run' dataset is outputted as a JavaScript Object Notation[4] (JSON) file at the end of every model run (i.e., after 1,825 time-steps). The model analysis explored four key outputs:

1. Total *Migrants* in each **state** (see A.17.13a);
2. Total **accepted offers** by *agent type*(s) (see A.17.13b);
3. *Migrants'* **precarity score** averaged by **pathway** (see A.17.13c); and
4. Composition of the **sociocentric migration network** (see A.17.13d).

Emergent results. The primary emergent properties of the model runs are the individual migration precarity scores (by pathway type) and the composition of the model's sociocentric network.

A.17.13a Output 1 – Migrants' states

The total migrants will be charted by which state (pre-migration, planning, transit, employed) they are in at each time-step starting from time-step 1 (t_1) until the end of the model run (t_{1825}). See Figure 12 for an example of the output graph.

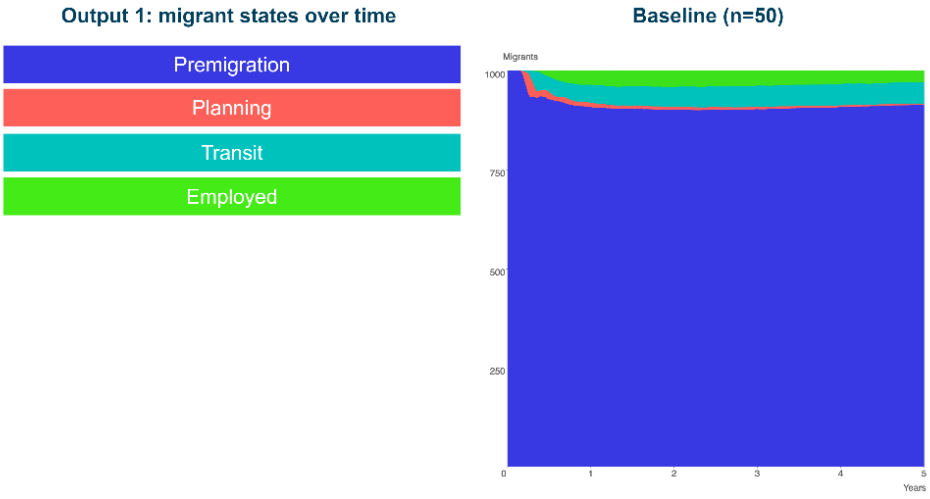


Figure 12. Output 1 – example graph

[4] A 'JSON' file stores simple data structures and objects in JavaScript Object Notation (**JSON**) format, which is a standard data interchange format. It is like a Comma-Separated Values (CSV) file.

A.17.13b Output 2 – Accepted offers

The cumulative total offers that have been charted by the type of agent making the offer (i.e., family, Myanmar Document-Broker, Recruiter, Smuggler, Facilitator, or Thailand Document-Broker). See Figure 13 for an example of the output graph.

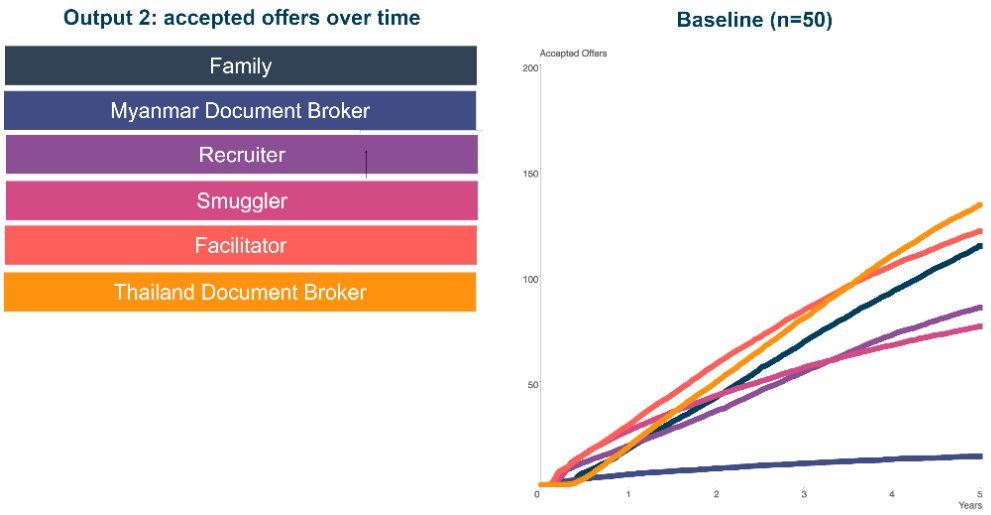


Figure 13. Output 2 – example graph

A.17.13c Output 3 – Precarity scores by pathway

The formalization of the 'precarity' score is informed by Hannah Lewis's work exploring conceptualizations of migrants experiences of *hyper*-precarity (35), Priya Deshingkar's work exploring brokered precarity in the Global South (36) and Myanmar specifically (37, 38), and by the empirical Myanmar-Thailand MMSNA conducted as part of this study (17). The **precarity** score is calculated for each migration starting in the time-step that migration costs are paid (Sub-Model 3, Rule 21). **Precarity** is a multi-dimensional score that includes indicators for the individual's current livelihood pressure, socio legal status (i.e., legal status affects social conditions), and destination knowledge and support that all contribute varying 'values' to the migrant's overall precarity score (Table 8).

Table 8. Individual precarity score indicator

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

The overall precarity score is calculated as an average of the sum of all individual migrations' precarity scores that used the same **pathway.** There are 4 possible pathways that represent all possible migration trajectories in the model and are mutually exclusive and defined by the types of offers the *Migrant* has accepted (Table 9).

Table 9. Pathway classifications

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

This score is dynamic as it responds to changes that occur through wage payments, family financial changes, documentation changes, influx of migrants, changes to debt, etc (Figure 14). The indicators included in the precarity score are chosen for the following reasons:

- **Debt (indicators 1&2)** indicates pressure to recover migration **costs**. Industry debt prevents migrants from *leaving* and family debt exceeding current wealth demotivates migrants from returning home.
- **Nuclear family wealth (3)** is a proxy for pressure to remit money home and current relative financial standing that may have motivated the migration in the first place.
- **Low wages (4)** increase financial pressure on the migrant, especially when in a destination with higher costs of living than their home area.
- **Documentation (5),** or lack thereof, increases the risks of deportation and exploitation and limits migrants' rights and security at destination. There appears to be an increasing vulnerability with distance from the border areas where irregular migration is more common and there is more opportunity to cross the border quickly if needed.
- **First migrations (6)** are usually characterised by more uncertainty due to a lack of familiarity with the context and how to navigate the context safely.
- **No family at destination (7)** means the migrant has less support to rely on if issues arise.
- **Knowledge of alternative jobs (8)** gives migrants an option to leave their current work, if exploitative or dangerous, without losing livelihood. No knowledge of viable and attractive alternative work increases the pressure migrants feel to stay at their current job despite the conditions.

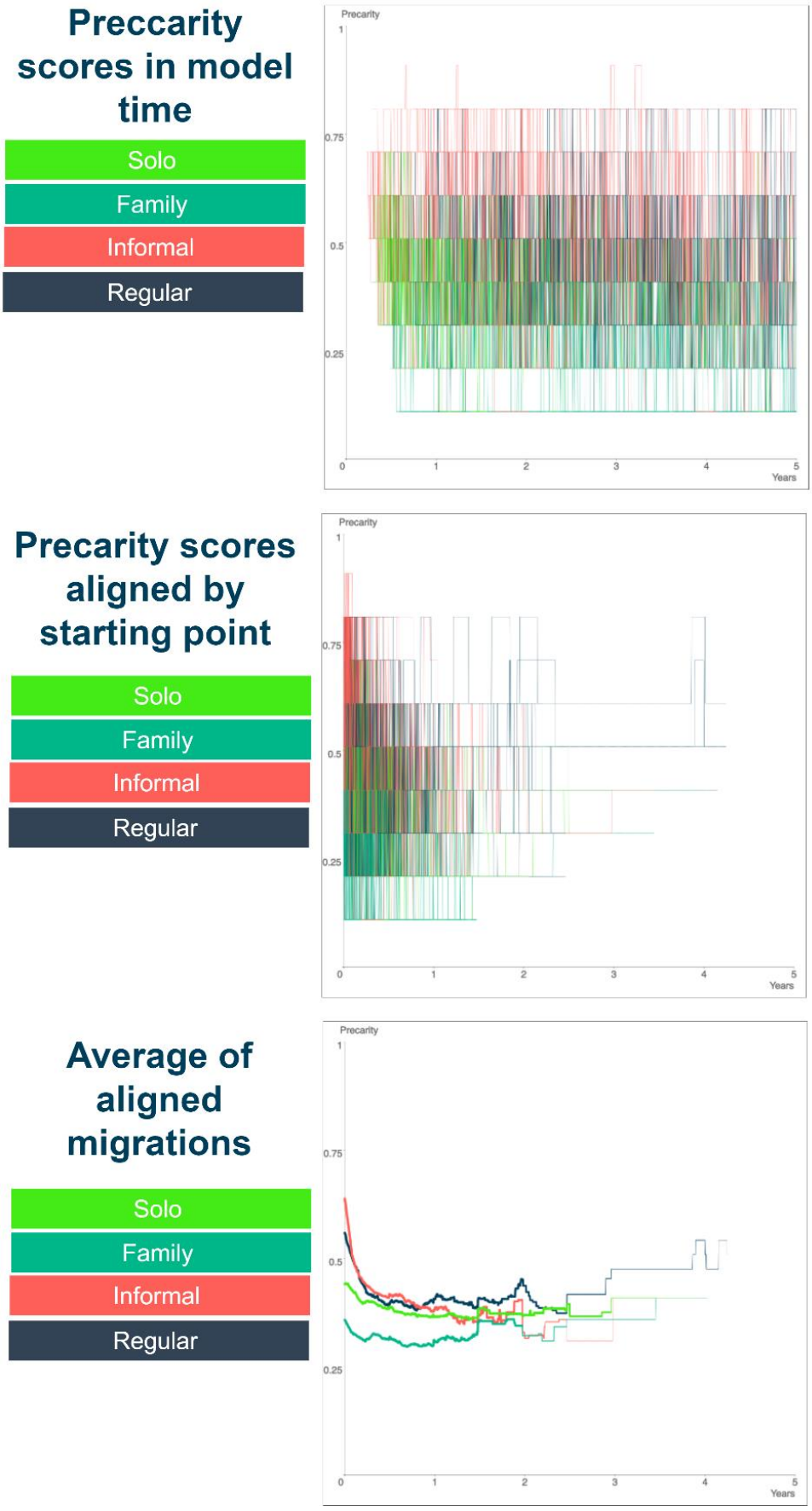


Figure 14. Output 3 – example graph

A.17.13d Sociocentric migration network density

The model run will produce an emergent sociocentric network that includes all *Migrants* that initiated at least one migration and all *agents* (family, intermediaries, employers) in those migrations' **migration networks**. The sociocentric network structure indicators (size, density, and diversity – see Table 10) will be captured for each year (n = 5) for one model run as a narrative case example of the emergence of the model's network. See Figure 15 for an example of the network visual.

Table 10. Network indicators

Network Indicators	Network Indicator Description
Size	Proportion of total agents in the network each time-step.
Density	Proportion of 'potential links' that are present in each time-step.
Diversity	Proportion of different agent classes and extended classes in the network at the end of the model run

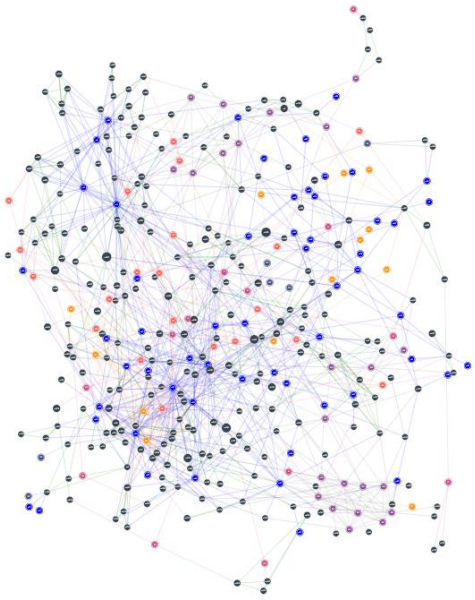


Figure 15. Output 4 – example emergent sociocentric network visualisation

Simulation scenarios. The analysis of the MyTh MaP-IN model considers three scenarios (one baseline and two experiments) and compares the dynamic observations across these scenarios.

The two experiments represent two key principles in the 'fair recruitment' intervention model that are specific to the migration planning and execution process. First, that recruitment should always be carried out within the law, and thus within official migration channels. In the case of the Myanmar-Thailand corridor this is the MOU process or post-arrival verification. Second, migrant workers should not bare the costs of recruitment services (i.e., Employer Pays Principle). These three scenarios are formalised in the ABM as follows:

1. **Baseline:** no pre-set scenario characteristics added to the model design.
2. **Legal Migration:** close both 'unofficial' border crossings so any *Migrant* attempting to cross the unofficial way immediately gets sent home.
3. **Employer Pays:** all *Recruiter* fees are set to 0.

Each scenario was run 50 times. The results for each output are shown as the mean values and ranges across all runs.

A.7.14 Implementation details

Mode implementation – The MyTh MaP-IN conceptual model and sub-model processes (as detailed in Section A.7.17) have been translated into model code written in JavaScript. The final ABM visualisations have also been written in JavaScript using the P5js and D3js visualisation libraries. This method of implementation was chosen in part to allow wider stakeholder access to the model in a browser-friendly viewing format (avoiding barriers of needing to download or navigate unfamiliar software such as NetLogo), as well as to enable more visual customisations to foster better model comprehension for non-technical audiences.

Model access – The MyTh MaP-IN model code, ODD+2D protocol, and supplementary documentation can be accessed via GitHub (39). The model can be viewed and interacted with via browser:

www.alysmcalpine.com/research/mythmapin/

The model is in the process of being made public via the CoMSES OpenABM model library (40).

A.7.15 Initialization

Initial state – At initialisation of the model (i.e., time-step = 0, or 't0') the environment is setup, and the *Migrant*, *Intermediary,* and *Employer* agents are created, as described in Section A.7.2. Some agent properties are pre-loaded at initialisation (e.g., motivation, threshold, vision) and other properties are left empty to be populated during the model run (e.g., migrations, plan, migration network). Table 11 details the population distribution of each agent's class by one other agent property (i.e., *Migrant-**state**, Intermediary-**extended class**, Employer-**sector**).* Table 2 details how the agent properties are initialised.

Table 11. Initialised agent populations in each sub-area

	Agent Groups	Origin sub-areas					Destination sub-areas				Total
Agent Class	*Migrant* **states** *Intermediary* **class** *Employer* **sectors**	Bago	Rakhine	Magway	Yangon	Myawaddy	Mae Sot	Tak	Phang Nga	Bangkok	
Migrant	**Pre-migration-** *Migrant*	100	100	200	400	200	-	-	-	-	1,000
	Planning- *Migrant*	-	-	-	-	-	-	-	-	-	0
	Transit- *Migrant*	-	-	-	-	-	-	-	-	-	0
	Employed- *Migrant*	-	-	-	-	-	-	-	-	-	0
Intermediary	**Recruiter**	-	-	-	20	8	-	-	-	-	28
	Facilitator	5	5	8	2	2	-	-	-	-	22
	Smuggler[1]	-	-	-	-	15	-	-	-	-	15
	Thailand-Document-Broker	-	-	-	-	-	3	-	5	10	18
	Myanmar-Document-Broker	-	-	3	5	3	-	-	-	-	11
Employer	**Manufacturing**	-	-	-	-	-	8	3	3	12	26
	Services	-	-	-	-	-	8	-	8	8	24
	Construction	-	-	-	-	-	5	-	3	5	13
	Fishing	-	-	-	-	-	-	-	3	6	9
	Agriculture	-	-	-	-	-	-	3	3	-	6
	TOTAL	105	105	211	427	228	24	6	25	41	1,172

1. Smugglers are initialised in a smaller Myawaddy sub-area within a constrained random walk to that area.

Run initial state variation – Model *runs* (i.e., repeated sets of 1,825 executed *time-steps*) will always be setup with the same default *environment,* number of *agents* in each sub-area, *value ranges* of agent properties (e.g., number of families in the model, threshold range), and *distributions of values* (e.g., proportion of migrants with the three different migration preferences). However, each individual *agent's* initialised *property values* will vary across the runs. The number of agents in the groups described in Table 11 are the default population distributions for each run across the sub-areas. The model will include some user-controlled parameters which the ABM user can interact with and adjust at the start of a model run to change some of the model's initialised values (See Section A.7.17).

Rationale for initialised collective and network values – The initial values of the agent types, locations, and links between *Intermediaries* were informed by the empirical egocentric network data and qualitative data (See Section A.7.16). The initialised unidirectional links (Agent A to Agent B) that are included in the model and what percentage of the time these links exist are detailed in Table 12.

- *Recruiters* can only be **linked** to *Employers* in their *Agency's* **roster**.
- *Smugglers* can only be l**inked** to *Employers* in their **offer's destination**.
- *Employers* can only be **linked** to *Thai-Doc-Brokers* in their **home** area.

Table 12. Initialised agent-agent links

'A' has link to 'B' x% of the time		AGENT B					
		Facilitator	Recruiter	Myanmar-Doc-Broker	Thai-Doc-Broker	Smuggler	Employer
AGENT A	Facilitator		✓ 25%			✓ 100%	✓ 25%
	Recruiter						✓ 100%
	Myanmar-Doc-Broker		✓ 10%				
	Thai-Doc-Broker						
	Smuggler						✓ 10%
	Employer				✓ 50%		

A.7.16 Input data

Data overview – The model does not use any direct input from empirical data files or data imported from other model data outputs. However, the structure and rules are informed by empirical data sources analysed using mixed-methods social network analysis (as described in Section A.7.4 and McAlpine and colleagues MMSNA paper (17)). The primary data analysed for this ABM included two datasets:

1. Structured egocentric network data and outcome variables formatted into three Comma Separated Values (CSV) files:
    - Migrant file – demographic and outcome data pertaining directly to the interviewee
    - alter file – demographic and behaviour data pertaining to all the alters the interviewee named and described in the participatory egocentric network mapping
    - Link file – the relational links between alters in the interviewee's egocentric network
2. Qualitative transcripts –text files coded according to a priori themes and themes that emerged through a deductive qualitative analysis approach.

Separate from these empirical datasets that informed the model rules, the model has an input data file called a 'config' file. Configuration data 'inputted' into the model is stored in a JSON file that populates the model with essential parameters as defined and described in the Sub-Model descriptions. Alternative configuration files can be exported via the model interface after using the parameter sliders to select the desired values. Separating initialisation data from the model code in this way allows for using different initialisation values for different model runs during analysis.

Data structure – The mixed methods empirical data were used to inform the agent entities, environment entities, and agent rules (1 & 2 below with some examples). The config file was used to generate the entities and properties in the model code in a structured manner. More detailed **data mapping** and

data patterns (i.e., the ODD+2D sections on the linkages between data sources and model design) are integrated into the Tables in Section A.7.17 that describes each model rule. The rationale for each rule, whether supported by empirical data or theory, is included there and informed by the findings detailed in McAlpine and colleagues' MMSNA paper (17). See Table 13 for an overview of the data input and config files.

Table 13. Data inputs and config file

Data type	Description
1. Structured data	• Origin and destinations determined the environment sub-areas. • Network nodes informed the Intermediary types. • Network events/interactions informed the agent rules. • Outcome variables (e.g., wages, deductions, work hours) informed the *Employer* variables.
2. Qualitative data	• Accounts of network interactions informed the agent rules, model stages, and order of execution. • Descriptions of decision-making processes and preference informed the decision-models.
3. Config File	• *Environment* names, locations, boundaries, subareas • *Agency* and *Document Office* names and locations • Quantity of *Migrant* agents in each *Environment* subarea • Quantity of *Intermediary* agents by class in each *Environment* sub-area • Quantity of *Employer* agents by sector in each *Environment* sub-area • Require documents and maximum employees for each sector • Probability distributions for *Intermediary-Intermediary* links • Probability distributions for *Intermediary-Employer* links • Probability distributions for *Employer-Intermediary* links • Properties for *Documents* including expiration, cost, and *Employer* id • Maximum and minimum money values for model's financial scale

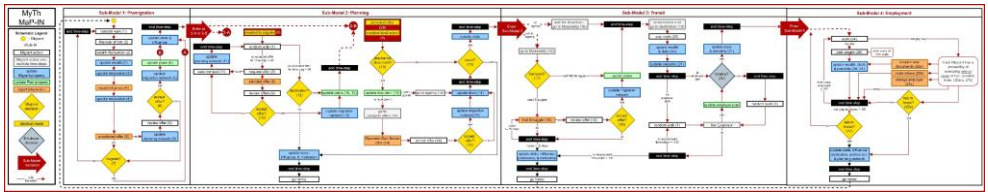
A.7.17 Sub-models

MyTh MaP-IN includes four sub-models:

1. Pre-migration
2. Planning
3. Transit
4. Employment

Sub-model design. The sub-models, presented sequentially in this section of the ODD+2D protocol, are written from the perspective of an individual *Migrant* agent. Each sub-model description includes a:

1) **narrative overview;**
2) **schematic diagram** (Figures 10-13, sub-model subsections of Figure 6 repeated below); and
3) **table of rules** (Tables 14-17, brief description, rationale, and model-based execution for every rule)



Repeated Figure 6. MyTh MaP-IN model schematic[5]

[5] Please note, if you are viewing this figure digitally you can zoom-in for detail, otherwise please refer to Figures 16-19 later in this section for larger versions of the individual Sub-Model schematics.

Model parameters – Please refer to the documentation on the entity properties (Table 2), agent-agent links (Table 12), and agent-agent interactions (Tables 5 and 6) to note the possible values or configurations of these model properties that are included in the sub-model rules.

User controlled parameters

The interactive interface includes the option to run the two experiment scenarios, as well as the baseline scenario, without needing to make changes to the model code. Future iterations of the model will include more user-controlled functions for more model exploration (e.g., changes to migrant preference distributions, changes to agent population totals and densities).

Sub-Model 1 – Pre-migration

Narrative Overview

The primary agent that executes the process in Sub-Model 1 (See Figure 16-19 and Table 14) is a *Pre-migration-Migrant*. A *Pre-migration-Migrant* decides if they want to migrate by either:

a) accepting an unsolicited **offer** to migrate from an *Employed-Migrant* in their **family** that is already at **destination**;
b) accepting an unsolicited **offer** to migrate from a *Facilitator* OR *Recruiter* within their **vision**; or
c) having a **motivation** to migrate that reaches or exceeds their **motivation threshold**.

Every time-step, a *Pre-migration-Migrant's* **motivation** changes based on their **nuclear family's relative average wealth** and the social **influences** they receive from family and from *Migrant* agents in their **vision**. In Sub-Model 1, an accepted **offer** populates a *Migrant's* **plan** with a **destination** and sometimes an **employer**. When a *Pre-migration-Migrant* decides to migrate, they update their **state** from 'pre-migration' to 'planning' and end the time-step. A *Planning-Migrant* starts the next time-step in Sub-Model 2. If they do not decide to migrate, a *Pre-migration-Migrant* repeats the **Sub-Model 1** process in the next time-step.

Figure 16 depicts the Sub-Model 1 process annotated with the rule numbers that correspond to Table 14. Table 14 presents the Sub-Model 1 *Migrant* agent rules in the order they are executed. The implicit condition for all Sub-Model 1 rules is that a *Migrant*'s **state** is 'pre-migration' and their **location** is within their **home** sub-area. Some Sub-Model 1 rules describe a *Pre-migration-Migrant's* response to rules that are 'fired' by other agents and Table 14 includes signposting to those corresponding rules in other Tables when relevant.

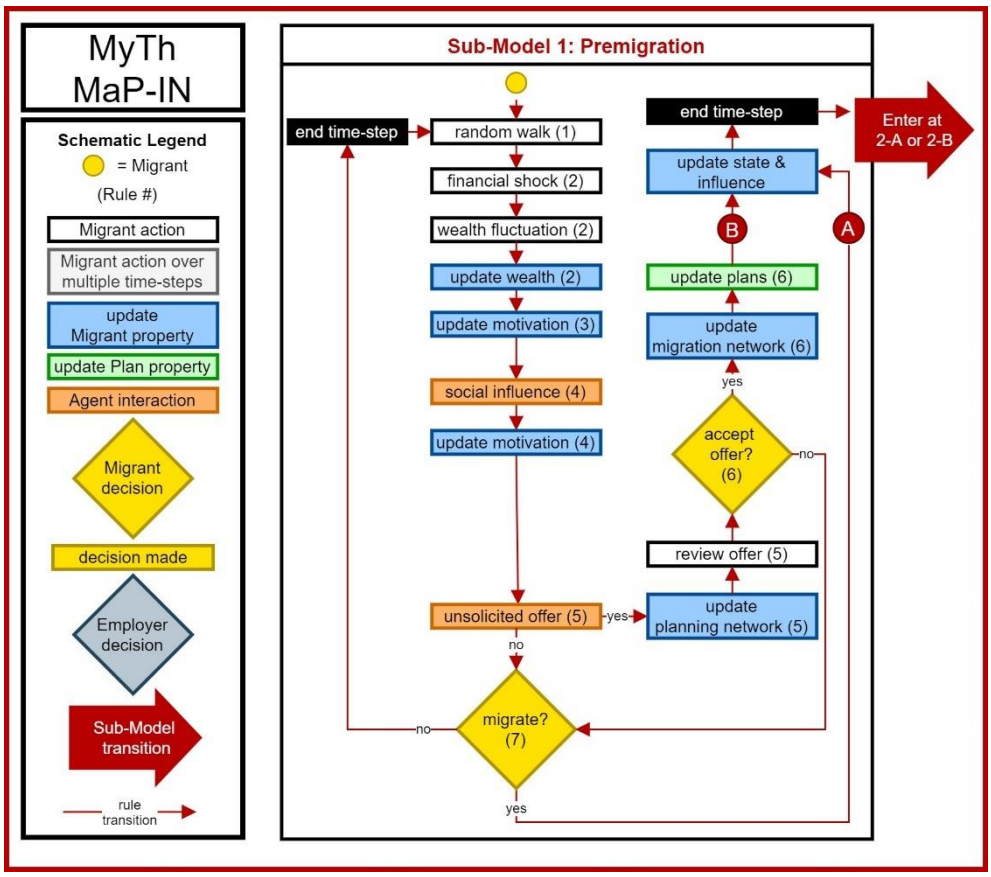
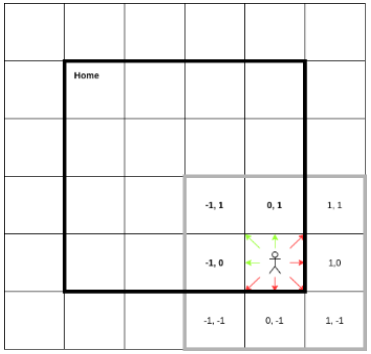


Figure 16. MyTh MaP-IN Sub-Model 1 schematic

Table 14. Sub-Model 1 rules

Rule description, rationale and calibration informed by McAlpine et. al.'s Myanmar-Thailand MMSNA study (17), University of Sussex's CHIME study (16), and the Myanmar Living Conditions survey (15).	**Model based rule** (IF-THEN or basic equation)
1. Migrant movement rules **1a. Migrant random walk rule.** A *Migrant* completes one random-walk movement to a cell in their surrounding Moore neighbourhood (3x3 grid that centers around their current location). **1b. Migrant random walk constraint.** A *Migrant* cannot random walk outside of their current sub-area (i.e., **home** in this case).  **Rationale:** Random walk incorporates stochastic movement that creates 'chance' opportunities for interaction among the agents. This pattern reproduces local interactions that reflect both serendipitous and routine points of contact that can occur when an agent is not executing 'destination' driven movement. These random movements are always within the bordered sub-area space as individuals are unlikely to go far from their geographic 'home' area unless they are migrating domestically (not included in this ABM) or internationally (occurs in future Sub-Models). These opportunities for contact capture the many local social interactions described in the MMSNA study qualitative narratives about influential social encounters leading up to the decision to migrate (direct exchanges with or indirect observations of co-workers, friends, community members, neighbours, even strangers including conversations about migration or observations of migration behaviours) (17).	**1a. Migrant random walk rule** *possibleAbsoluteStep = { [-1,1], [0,1], [1,1], [1,0] , [1,-1] , [0,-1] , [-1,-1] , [-1,0] }* *proposedAbsoluteStep = randomly selected possibleAbsoluteStep* **1b. Migrant random walk constraint** IF *location(t-1) + proposedAbsoluteStep is within agent's sub-area* THEN *location(t) = location(t-1) + proposedAbsoluteStep* ELSE *Continue to randomly select proposedAbsoluteStep until:* *(location(t-1) + proposedAbsoluteStep) is within the agent's sub-area* *location(t) = location(t-1) + proposedAbsoluteStep* END

2. Wealth change rules Migrant **wealth** can change due to infrequent **financial shocks** and/or regular **wealth fluctuations**. **2a. Financial shock rule.** There is a small random chance (0.01%) every time-step that **wealth** decreases by 30% (i.e., wealthChange = 0.7). **2b. Wealth fluctuation rule.** Once every 30 time-steps, **wealth** fluctuates by a small random amount. The **wealth fluctuation** time-step varies across *Migrants*. At model initialisation, a **monthly wealth fluctuation offset** is randomly selected between 1-30 which is used to determine when the wealth fluctuation rule is executed for an individual *Migrant* during Sub-Model 1. N.B. The % symbol in this rule is not being used to represent a percentage, but instead it is a common programming notation for the modulo operator (i.e., returns the remainder left over when one operand is divided by a second operand). **2c. Wealth change rule.** The total **wealth change** (**financial shock** + **fluctuation**) is applied to the *Migrant's* current **wealth**. **2d. Wealth constraint.** Wealth is constrained so it cannot be less than 0 or more than 1. **Rationale:** Wealth is a dynamic variable. **Regular small fluctuations** represent more predictable changes to monthly profit from pre-migration livelihood activities, such as 'normal' harvest. Since this fluctuation happens 'monthly' in the model, the initialised value of migrant 'wealth' is an approximate monthly income based on average daily spending in Myanmar rural and urban areas (15). In keeping to the model purpose and aim to keep the model as simple as appropriate, the model assumes *Pre-migration-Migrants* do not have savings, debt, or multiple incomes and the model also does not explicitly execute pre-migration employment activities. **Financial 'shocks'**, larger unexpected and sudden decreases to wealth, were reported as drivers of migration in the MMSNA and the CHIME study. Shocks included, for example, unexpected medical expenses, loss of land/property, loss of employment, climate events, etc. These shocks decrease wealth a more significant amount which is more likely to trigger the decision to migrate than a small negative fluctuation.	**2a. Financial shock rule** *wealthChange = 1 with probability = 0.9999* *wealthChange = 0.7 with probability = 0.0001* **2b. Wealth fluctuation rule** *monthlyWealthFluctuationOffset = random number between 1-30 set at initialisation and static throughout run* IF (*current timestep – monthlyWealthFluctuationOffset)%30 = 0* THEN *add randomly selected amount between -0.05 to 0.05 to wealthChange* END **2c. Wealth change rule** *wealth(t) = wealth(t-1) * wealthChange* **2d. Wealth constraint:** *wealth(t)* = MIN[1,MAX[0,wealth(t)]

3. Wealth and motivation rules

A *Pre-migration-Migrant's* relative **average nuclear family wealth** can affect their **motivation** to migrate. A global parameter used in this rule is: ***wealthMotivationChange = 0.01***

3a. Relative average nuclear family wealth rule. Every time-step, **average nuclear family wealth** is compared to all families in the home sub-area to determine relative wealth.

3b. Wealth and motivation rule. If a *Planning-Migrant's* **average nuclear family wealth** compared to all **average nuclear families' wealth** in their **home** sub-area, is in the lowest 40% or within the 60-80% range then there is no change to **motivation**. If their **average nuclear family wealth** is in the 20-60% range their **motivation** increases IF their migration **motivation threshold** is already equal to or lower than 0.8. If a *Planning-Migrant's* **average nuclear family wealth** is in the top 20% their **motivation** decreases till a certain point. In short:

<40%	**40-60%**	**60-80%**	**80-100%**
no change	Increase motivation (IF threshold ≤ 0.8)	no change	Decrease motivation

3c. Motivation constraint. Motivation is constrained so it cannot be less than 0 or exceed 0.99.

Rationale: Evidence on the relationship between poverty and international labour migration indicates that low-middle income households are most incentivised by the international wage differences (41, 42). The Myanmar Living Condition survey reports that, *"economic migration abroad is higher among the non-poor, while the poor are more likely to be temporary economic migrants working within Myanmar. . . . Only those who can afford these costs and who deem temporary migration abroad to be profitable may decide to follow this route."* (15) Relatively 'high' income households are less incentivised to migrate for low wage international work, although they might migrate for education or specialised roles outside of the scope of this ABM. Thus, high wealth households experience a decreased motivation to migrate. Labour and development economist Oded Stark theorised that relative wealth, not always absolute wealth, is a strong influence on motivation to migrate (43). This theory has been supported by empirical evidence, including the MMSNA study informing this ABM, which reported that many respondents described 'financial aspirations' in relation to other households or peer groups, for example, wanting to be 'better off' or have a new house like other return migrants (17).

Finally, household financial motivations to migrate often fall on select family members. The Myanmar Living Conditions survey reports an increasing likelihood to migrate age 15-20 that then steadily decreases for ages of 25-60 (15). In Myanmar, it is most often the young adults and historically the men that migrate abroad for work (16). This rule uses the migration 'threshold' as a proxy for demographic propensity to migrate and excludes migrants with high thresholds from a household wealth influenced motivation change.

3a. Relative average nuclear family wealth rule

For each home sub-area:
Create a temporary array called *subAreaWealths* that will hold all *averageNuclearFamilyWealth* referenced to their *nuclearFamilyID*.

For each family:
averageNuclearFamilyWealth = sum of wealth of nuclearFamily agents/total nuclearFamily agents
add averageNuclearFamilyWealth to subAreaWealths array for their home sub-area

For each sub-area:
sort nuclearFamilyIDs in subAreaWealths array in ascending order by their averageNuclearFamilyWealth

3b. Wealth and motivation rule

IF *averageNuclearFamilyWealth < 40% of families in home subAreaWealths*
THEN
    no change to motivation

ELSE IF *averageNuclearFamilyWealth > 60% AND < 80% of families in home subAreaWealths*
THEN
    no change to motivation

ELSE IF *averageNuclearFamilyWealth ≥ 40%* AND *≤ 60% of families in home subAreaWealths*
THEN
    IF *motivationThreshold ≤ 0.8*
    THEN
        motivation(t) = motivation(t-1) + wealthMotivationChange
    ELSE
        no change to motivation
    END

ELSE IF *averageNuclearFamilyWealth > 80% of families in home subAreaWealths*
THEN
    motivation(t) = motivation(t-1) - wealthMotivationChange
END

	3c. Motivation constraint: *motivation(t)* = MIN[0.99,MAX[0,*motivation(t)*]]
4. Influence and motivation rules A *Pre-migration-Migrant's* incoming social **influences** can affect their **motivation** to migrate. Two global parameters used in this rule is: ***influenceMotivationChange = 0.001*** ***influenceThreshold = 0.25*** **4a. Weighted average influence rule.** Every time-step, a *Pre-migration-Migrant* receives **influences** from extended family *Migrants* (in all locations) and non-family *Migrants* within their **vision**. All incoming influences are used to find a **weighted average influence**. **Influence** from family *Migrants* and *Migrants* with at least one completed migration are given double weighting. **4b. Influence and motivation rule.** If the **average weighted influence** is a certain amount higher or lower than current **motivation,** then **motivation** increases or decreases, respectively. If motivation changes, then the **motivation constraint** (Rule 3c above) is executed. N.B. Motivation(t) may have already been updated in Rule 3. This additional change to motivation(t) would add to that change does not overwrite that change. For within-rule clarity, we use (t) and (t-1) to refer to an update to current motivation (t) using the most recent value for motivation (t-1). **Rationale:** The MMSNA study highlights the range of social network interactions (encouragements, discouragements, expectations, behaviour modelling, etc) that influence motivations to migrate (17). The most influential exchanges described were often between prospective migrants and their family or 'returnee' migrants in their communities. Therefore, the influence of those agents have been double weighted. Individual migrants sometimes responded to these influences differently (e.g., 'I *had* to come because my husband made me' versus 'My mother did not want me to come but I made my *own* decision') (17). Given these anecdotal accounts of heterogenous responses to social influences, the social influence rule is probabilistic. The MMSNA study and other studies we are aware of, do not offer quantitative distributions of these varied responses so for this first model we have resigned to make it equally likely for a migrant's motivation to be influenced or not.	**4a. Weighted average influence rule** *weightedTotalInfluence = (sum influence of extended family Migrants)*2 +* *(sum influence of Migrants in vision with completed migrations ≥ 1)*2 +* *(sum influence of Migrants in vision with completed migrations = 0)*1* *totalInfluencers = (total extended family Migrants whose influence was counted)*2 +* *(total Migrants with completed migrations ≥ 1 whose influence was counted)*2 +* *(total Migrants with completed migrations = 0)*1* *weightedAverageInfluence = weightedTotalInfluence/totalInfluencers* **4b. Influence and motivation rule** IF *weightedAverageInfluence > motivation(t-1) + influenceThreshold* THEN *motivation(t) = motivation (t-1) + influenceMotivationChange with probability = 0.5* *no change to motivation(t) with probability = 0.5* ELSE IF *weightedAverageInfluence < motivation(t-1) - influenceThreshold* THEN *motivation(t) = motivation (t-1) - influenceMotivationChange with probability = 0.5* *no change to motivation(t) with probability = 0.5* ELSE *no change to motivation(t)* END **Motivation constraint rule** (Rule 3c)

5. Unsolicited offers rules

5a. Receive unsolicited offer rule. Agents that make a direct **offer** to a *Migrant* are added to the **planning network**. At this stage, an **offer** can be made to a *Pre-migration-Migrant* by an *Employed-Migrant* in their extended family member or a *Recruiter* or *Facilitator* within their **vision**. Any offer, in any Sub-Model stage of the ABM, might also include links (through the agent making the **offer**) to other agents which then presents the option for a **'combined offer'**. See Rule 25b and Rule 29 for the corresponding offer rules.

5b. Review unsolicited family offer rule. Any unsolicited **offers** (and associated **combined** offers) from an *Employed-Migrant* are reviewed first. A **combined offer** from an *Employed-Migrant* uses the agent IDs in that *Migrant's* **migration network** (i.e., any *Intermediary* they used for their own **migration**). If the *Pre-migration-Migrant's* **motivation** is already within 0.1 of their **motivation threshold**, then they identify the **best offer** based on their **preference**.

5c. Review unsolicited Intermediary offer rule. If the *Migrant* has not received any family **offers**, or they did not identify a **best offer** from those received, then they repeat a similar set of rules to review unsolicited *Intermediary* **offers** and **combined offers**.

Rationale: The MMSNA identified three categories to describe how migrants decided to migrate (i.e., the point that the migration was initiated) using the structured data on network actors involved in the decision to migrate and qualitative data on the process of deciding to migrate. The three categories include: 1) accepting an unsolicited opportunity to migrate presented by a close social tie, usually family; 2) accepting an unsolicited opportunity to migrate presented by an intermediary actor, usually a 'facilitator' or 'recruiter'; or 3) being motivated 'enough' to start planning to migrate irrespective of any known opportunity to migrate. This rule incorporates the first two options (Rule 7 addresses the third)/ Opportunities to migrate are framed as 'offers' to migrate. In this 'pre-migration' state, when migrants are not actively seeking out migration plans, the offer selection process gives priority to family offers as this was how the majority (50%+) of migrations were initiated in the MMSNA study, which confirmed other research in the Myanmar-Thailand corridor that socially mediated migrations are the most common pathway for Myanmar migrants (18, 44). The MMSNA qualitative narratives indicated that most migrants accepting these unsolicited opportunities had pre-existing motivation or interest to migrate, so this rule includes a motivation condition. A migrant's motivation must already be within a certain range from their threshold to consider accepting an unsolicited offer. This condition range is smaller for accepting an intermediary offer compared to a family offer – again to recognise the increased use of and trust in family facilitated migration (17, 44).

Separate from the 'global'[1] preference for a family offer, every migrant also has a 'preference' (e.g., preference to work in a factory or hospitality) used as a possible decision condition at multiple points in the model. These preferences were identified thematically in the MMSNA qualitative analysis and concurred with the migration decision influences reported by the CHIME study survey data that

5a. Receive unsolicited offer rule

IF *unsolicited offer received*
THEN
    planningNetworkSize(t) = planningNetworkSize(t-1) + total agents offering
    planningNetwork(t, planningNetworkSize(t)) = id of agent(s) offering
    Review unsolicited family offer rule (Rule 5b)
ELSE
    Migration motivation decision (Rule 7)
END

5b. Review unsolicited family offer rule

IF *family offer received* AND *motivation(t) > motivationThreshold - 0.10*
THEN
    IF *any offer satisfies preference*
    THEN
        randomly select bestOffer
    ELSE
        randomly select bestOffer with (probability = 0.4)
        do not select bestOffer with (probability =0.6)
    END
ELSE
    Review unsolicited Intermediary offer rule (Rule 5c)
END

5c. Review unsolicited Intermediary offer rule

IF *intermediary offer received* AND *motivation(t) > motivationThreshold - 0.05*
THEN
    IF *any offer satisfies preference*
    THEN
        randomly select bestOffer
    ELSE
        randomly select bestOffer with (probability = 0.2)
        do not select bestOffer with (probability =0.8)
    END
ELSE
    Migration motivation decision (Rule 7)
END

informed the baseline models distribution of these preferences in the migrant population (16, 17). See full description of migrant 'preferences' in *Section A.7.2 – Agent entities* of this document. [1] 'Global' meaning a parameter or rule condition set for the whole model, irrespective of agent attributes, not referencing the literal 'world'.	
6. Unsolicited offer decision If the *Pre-migration-Migrant* identified a **best offer** (Rule 5), then they decide whether to accept that **best offer**. A global parameter used in this rule is: ***increasedInfluenceRate*** *= 1.1* **6a. Unsolicited offer decision.** If a **best offer** was identified from the unsolicited offers, then the *Migrant* accepts the offer 90% of the time. If they accept the offer, they add agent(s) 'offering' (including any **combined offer** links) to their **migration network**, update their **state** to 'planning', add a new **migration** to their **migrations** array, update the **plan** properties in that **migration** to match the properties of the **offer** they have accepted, and update their **influence**. If they do not accept the **best offer,** then there is no change **6b. Influence constraint.** Influence is constrained so it cannot be less than 0 or more than 1. **Rationale:** Once an offer is made and Migrant have met their motivation threshold, preference, and employer conditions it is assumed that any remaining offer is highly suitable to the Migrant and they would accept in most cases, subject to some probability that they might decline in case they changed their mind or some other obstacle to their migration arose. This latter option is not represented in the empirical data because of the sampling approach which was only with migrants that were in Thailand and thus had completed migration. However, for this model we did not assume that all migrants do continue through migration at each stage and thus there is always a small probability of 'drop out' for unspecified reasons in the model. Migrants that decide to migrate have an increased influence on other Migrants. This assumption is informed by the empirical analysis as many migrants named other community members planning or returning from migration as strong influences on their own decision is that migrants planning to migrate can have an indirect or direct effect on others in their home area that see they are planning to migrate and might discuss these plans with them or just observe from afar and be more inclined to also migrate.	**6. Unsolicited offer decision** IF *bestOffer* ≠ empty THEN *accept offer with probability = 0.9* *migrationNetworkSize(t) = migrationNetworkSize(t-1) + total agent(s) making offer* *migrationNetwork(t, migrationNetworkSize (t)) = id of agent(s) making offer* *state(t) = planning* *add new migration to migrations array and give it empty properties including 'plan'* *plan(t) properties are populated by the accepted offer properties* *influence(t) = influence(t-1) * increasedInfluenceRate* **6b. Influence constraint:** *influence(t) =* MIN[1,MAX[0,*influence(t)*]] *reject offer with probability = 0.1* *no change to migrationNetwork, migrations, or state* ELSE **Migration motivation decision** (Rule 7) END

Migration motivation decision A global parameter used in this rule is: ***increasedInfluenceRate*** *= 1.1* If the *Pre-migration-Migrant* did not identify a **best offer** (Rule 5) or did not accept a **best offer** (Rule 6), then they decide if they are motivated 'enough' to migrate anyway. If a *Migrant's* **motivation** to migrate is equal to or greater than their **motivation threshold** then they decide to migrate, update their **state** to 'planning', add a new **migration** to their **migrations** array, and update their **influence**. Otherwise, there is no change. **Rationale:** This rule models the third category of migration 'initiation' – being motivated 'enough' to migrate irrespective of any known or accepted offers, as described in Rule 5. These represent the cases in the MMSNA where individuals said their *final* decision was made completely independently of any other actors in their network (17). Their 'high' motivation was often a result of positive social influences and/or financial incentives/pressures to increase, all of which are socially embedded in the model, but their decision was independent of any known connections to destination or work. This probabilistic rule accounts for the possibility that a migrant could encounter a range of barriers (e.g., family bans the idea to migrate, physically unable, etc.) despite being motivated enough to migrate, these cases were not in our sample due to the sampling method, but the model assumes different points of 'drop out' throughout the model.	**7. Migration motivation decision** IF *motivation(t) ≥ motivationThreshold(t)* THEN *state(t) = planning with (probability = 0.9)* *add new migration to migrations array and give it empty properties including 'plan'* *influence(t) = influence(t-1) * increasedInfluenceRate* **Influence constraint** (Rule 6b) *no change to state(t) or influence(t) with (probability = 0.1)* ELSE *no change to state(t), migrations, or influence(t)* END End time-step

Sub-Model 2 – Planning

Narrative Overview

The primary agent that executes the process in Sub-Model 2 (see Figure 17 and Table 15) is a *Planning-Migrant* whose primary goal is to have at least a partial migration **plan** and to leave **home**.

A *Planning-Migrant's* actions and decisions depend partly on how they decided to migrate in Sub-Model 1 (i.e., they accepted an unsolicited **offer** OR they were **motivated** 'enough' without an offer). An accepted unsolicited **offer** populates a *Migrant's* **plan** properties before they enter Sub-Model 2 whereas motivated without an offer does not populate **plan** properties in Sub-Model 1. Sub-Model 2 is divided into **2-A** and **2-B** to account for this distinction (see Figure 17).

The final decision in Sub-Model 2 is whether to leave **home** or discontinue their **migration**. A *Planning-Migrant* must have a **destination plan** to leave home. In Sub-Model 2, a migration **plan** can be populated by:

a) accepting an unsolicited or solicited **offer** from an *Employed-Migrant* in their **family**;
b) accepting a solicited **offer** from an *Intermediary* within their **vision**; and/or
c) deciding aspects of their migration **plan** independent from **offers**.

Unlike Sub-Model 1, in which all relevant steps are executed in a single time-step and repeated in the next time-step, in Sub-Model 2 only certain steps are executed in each time-step and the duration of Sub-Model 2 depends on where a *Migrant* starts Sub-Model 2, interactions, offers, and decisions. If a *Planning-Migrant* decides to leave they update their **state** to 'transit', but if they decide not to leave their **state** reverts to 'pre-migration'. A *Transit-Migrant* starts the next time-step in Sub-Model 3. A newly 'reverted' *Pre-migration-Migrant* walks **home**, decreases their **motivation** to migrate, and starts the next time-step back in Sub-Model 1.

Figure 17 depicts the Sub-Model 2 process annotated with the rule numbers that correspond to Table 15. Table 15 presents the Sub-Model 2 *Planning-Migrant* agent rules in the order they are executed. Again, like Table 14, it is implicit in Table 15 rules that a *Migrant* agent's **state** is *'*planning'.

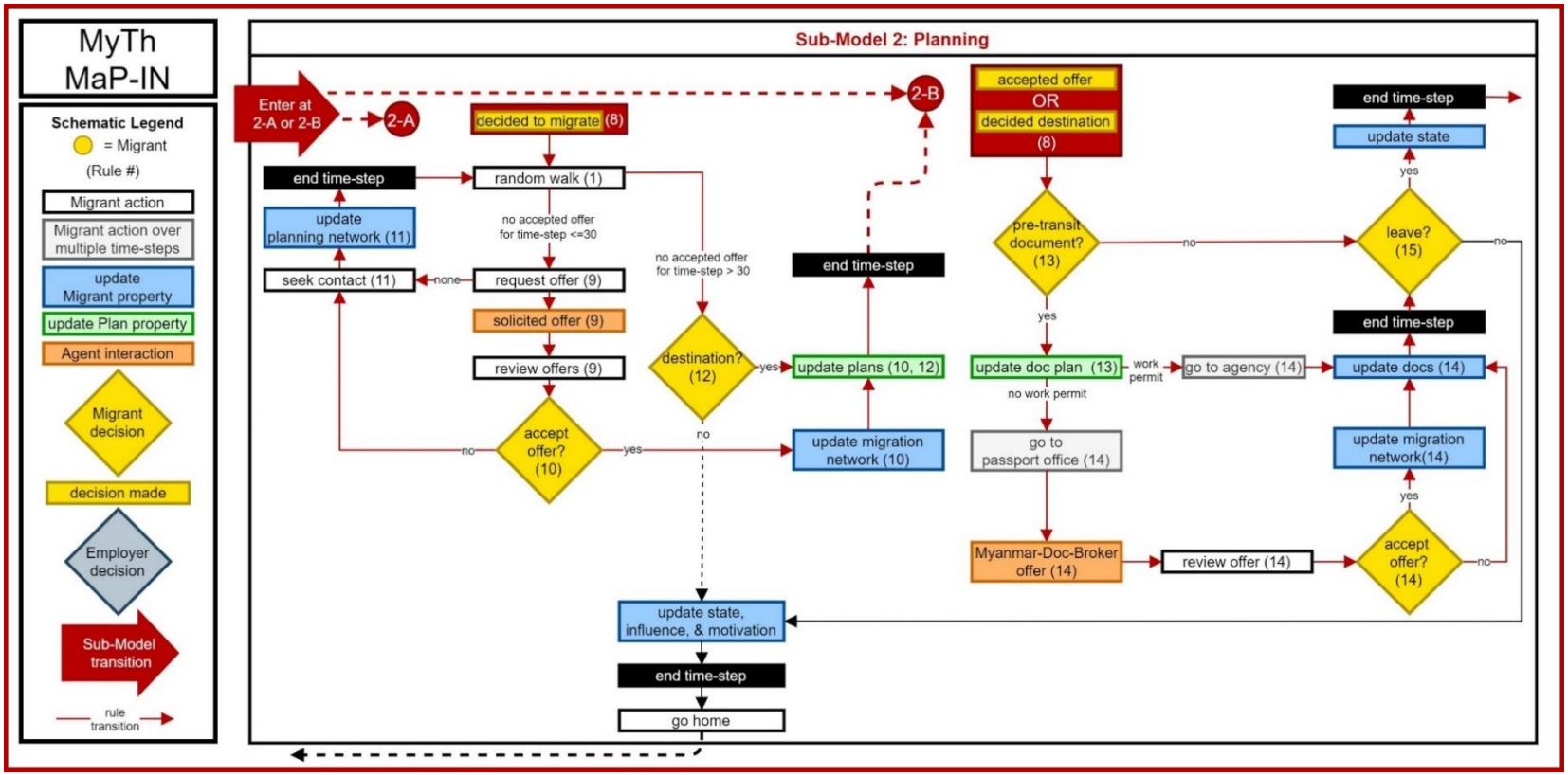


Figure 17. MyTh MaP-IN Sub-Model 2 schematic

Table 15. Sub-Model 2 rules

Rule description, rationale and calibration informed by McAlpine et. al.'s Myanmar-Thailand MMSNA study (17), University of Sussex's CHIME study (16), and the Myanmar Living Conditions survey (15).	**Model based rule** (IF-THEN or basic equation)
8. Sub-Model 2 starting place rule A *Planning-Migrant* starts Sub-Model 2 at either '2-A' or '2-B' depending on whether they have already accepted an **offer** (i.e., **migrationNetwork** ≥ 1). A *Migrant* without an accepted **offer** random walks and starts the 2-A process (Rule 9). A *Migrant* with an accepted **offer** starts the 2-B process (Rule 13). **Rationale**: The MMSNA study found that there is a pathway dependency between migration initiation and planning steps (17). *Migrants* that decided to migrate based solely on their motivation then sought out migration options from their known networks and surrounding community, whereas migrants that decided to migrate by accepting an offer now had plans already in place without needing to 'shop around' in the same way. Sub-Model 2-A and 2-B represent these two forks in the early planning stage based on initiation, again which was informed by the MMSNA structured data.	**8. Sub-Model 2 starting place rule** IF *migrationNetwork(t) is empty* THEN **Random walk rule** (Rule 1) *start Sub-Model 2-A* - **Solicited offer rules** (Rule 9) ELSE *no movement* *start Sub-Model 2-B* - **Pre-transit documentation decision** (Rule 13) END

9. Solicited offer rule

A *Planning-Migrant* without an accepted **offer** requests offers, possibly receives offers, and then review offers to identify a **best offer**. Rule 9 is a slightly extended and adapted version of Rule 5.

9a. Request offers rule. A *Planning-Migrant* can spend up to 30 time-steps requesting **offers** from their **planning network** (dynamic array of agents). After 30-time-steps without an accepted **offer** they must decide their destination. See request response rules in Rule 24b and Rule 30.

9b. Receive solicited offers rule. If any solicited **offer(s)** are received, the *Migrant* reviews the **offer(s).** If no **offer** is received, they 'seek new contacts' for their **planning network**.

9c. Review solicited offers rule. If only one solicited **offer** (with no **combined offer**) is received, this is, in effect, the **best offer.** If more than one **offer** is received, the *Migrant* identifies the **best offer** based on their **preference**. If none of the **offer(s)** satisfy their **preference,** then they randomly select a **best offer** 50% of the time. If they do not select a best offer then they seek contacts (Rule 11) to be able to ask for more **offers** in the next time-step.

Rationale: The MMSNA study reports that individuals that had decided to migrate but did not yet have plans on where to go or work would look for migration advice or 'leads' in whatever convenient networks of contacts they were already aware of (planning network) or new contacts they would make, such as extended family abroad, returned migrants at home, or intermediaries working nearby (17). Often these connections were made before leaving home, but in some rarer cases, a migrant would leave home without any assisted plans. After one month of exhausting possible leads a *Planning-Migrant* in the model has the option to choose their own destination. The choice of a one-month threshold is an estimate based on empirical evidence that it takes most migrants a few weeks up to a few months to complete migration. Assuming some of this time has already passed in the decision process and more time is needed to complete the migration, we have chosen one-moth for this seeking contact phase. This temporal condition is not informed directly by the empirical MMSNA since we did not capture on average how long migrants attempted to find contacts and assume that, in reality, it is likely to be a range of time migrants take to complete this process before deciding to move on independently.

9a. Request offers rule
IF *durationPlanning(t) ≤ 30*
THEN
    request offer from planningNetwork(t)
    Receive solicited offers rule (Rule 9b)
ELSE
    do not request offer from planningNetwork(t)
    Destination decision (Rule 12b)
END

9b. Receive solicited offers rule
IF *solicited offer(s) received*
THEN
    Review solicited offers rule (Rule 9c)
ELSE
    Seek contacts rule (Rule 11)
END

9c. Review solicited offers rule
IF *solicited offer(s) received*
THEN
    IF *any offer satisfies preference*
    THEN
        randomly select bestOffer
        Accept best solicited offer decision (Rule 10)
    ELSE
        randomly select bestOffer with probability = 0.5
        Seek contacts rule (Rule 11) *with probability = 0.5*
    END
ELSE
    Seek contacts rule (Rule 11)
END

10. Accept best solicited offer decision If the *Planning-Migrant* has identified a **best offer** from their solicited offers, they accept the **offer** 90% of the time. If they accept the offer, they add the agent making the offer to their **migration network** and update the **plan** properties in that **migration** to match the **offer** properties they have accepted. If they do not accept the **best offer**, then there is no change, and they seek new contacts. **Rationale:** This rule assumes that by this stage, most migrants have considered this option, and alternatives, enough to warrant them to accept or else they would not still be considering the offer. As other rules in this ABM have done, this rule leaves a probabilistic potential to 'reject' for any range of reasons not represented in the data as these interviews were beyond the scope of our sampling frame.	**10. Accept best solicited offer decision** IF *bestOffer* ≠ empty THEN *accept offer with probability = 0.95* *migrationNetworkSize(t) = migrationNetworkSize(t-1) + total agent(s) offering* *migrationNetwork(t, migrationNetworkSize (t)) = agent id(s) offering* *plan(t) properties are populated by accepted offer properties* *reject offer with probability = 0.05* *no change to migrationNetwork(t) or plan(t)* **Seek contacts rule** (Rule 11) ELSE *no change to migrationNetwork(t) or plan(t)* **Seek contacts rule** (Rule 11) END End time-step

11. Seek contacts rule

If a *Planning-Migrant* did not receive any **offers** or rejected their **best offer,** then they try to add new agents ('contacts') to their **planning network** in preparation for the next time-step. A *Planning-Migrant* adds all agents that meet the criteria of any of these groups:

1. *Employed-Migrant* in **extended family**;
2. *Intermediary* from a returnee *Migrant's* **planning network** if 'returnee' is within **vision**; or
3. *Intermediary* within expanded **vision** (vision x2).

This rule creates a temporary '**new contacts**' array to store these agent IDs temporarily before adding them all to the *Planning-Migrant's* **planning network.**

Rationale: The MMSNA structured network data indicates that social contacts that had migrated previously, especially family, and intermediaries through social networks were key sources of migration information, advice, and services at the early planning stages (17). Future iterations will also consider the influence of 'weak ties'.

11. Seek contacts rule

newContactsSize = 0
newContacts = empty

IF *bestOffer* = empty OR *bestOffer rejected*
THEN

IF *extended family agent's state = employed*
THEN
newContactsSize = total agents that meet the conditions
add id of agent(s) that meet the conditions to newContacts array
ELSE
no change to newContactsSize or newContacts
END

IF *Migrant within vision with (completed migrations > 0)*
THEN
newContactsSize is increased by total intermediaries in that Migrant's planningNetwork(t)
add id of intermediaries to the newContacts array
ELSE
no change to newContactsSize or newContacts
END

IF *Intermediary is within expanded vison*
THEN
newContactsSize is increased by total agents that meet the conditions
add id of agent(s) that meet the conditions to newContacts array
ELSE
no change to newContactsSize or newContacts
END

planningNetworkSize(t) = planningNetworkSize(t-1) + newContactsSize
planningNetwork(t, planningNetworkSize(t)) = id(s) in newContacts array
END
End time step

12. Destination decision

If a *Planning-Migrant* has not accepted an **offer** for more than 30 time-steps, they must decide whether to continue planning and choose a **destination** or whether to return **home**.

A global parameter used in this rule: ***decreasedMotivationRate= 0.9***

12a. Continue planning decision. A *Planning-Migrant* without an accepted **offer** has a 10% chance of deciding to discontinue migration, updating their **state** to 'pre-migration', updating their **motivation** to be slightly less than their initialised **motivation**, and, finally, they deactivate the current **migration** in their **migrations** array.

12b. Destination decision. If a *Planning-Migrant* decides to continue their **migration,** they then decide their **destination plan** based on their **preference**.

Rationale: The MMSNA and CHIME study findings on the influences on migration decision making reported that multiple factors (formalised as 'preferences' in the MyTh MaP-IN ABM) influenced migration decision making, including the destination decision (16, 17).

12a. Continue planning decision

IF *durationPlanning(t) > 30* AND *no offer has been accepted*
THEN
state(t) = pre-migration with (probability = 0.10)
motivation(t) = initial motivate decreasedMotivationRate*
Motivation constraint (Rule 3c)
deactivate current migration

state(t) = planning with (probability = 0.90)
no change to state(t), motivation(t), or migration
Destination decision (Rule 12b)
END

12b. Destination decision

IF *decided to continue planning*
THEN
IF *preference = social*
THEN
planDestination(t) = destination with the most home migrants
END

IF *preference = family*
THEN
planDestination(t) = destination with any family
END

IF *preference = sector* OR *wage*
THEN
planDestination(t) = 'bangkok'
END

IF *preference = proximity*
THEN
planDestination(t) = 'mae sot'
END

IF *preference = intermediary* OR *work* OR *fees* OR *legal*
THEN
planDestination(t) = 'mae sot' with (probability = 0.4)
planDestination(t) = 'bangkok' with (probability = 0.4)

	planDestination(t) = 'phang nga' with (probability = 0.2) END END End time step
Sub-Model 2-B begins here	
13. Pre-transit documentation decision **13a. Pre-transit documentation decision.** A *Planning-Migrant* without a **documentation plan** decides whether to get a passport or work permit *before* entering Thailand. **13b. Find Recruiter rule.** If a *Migrant* decides they want a work permit but does not have a *Recruiter* in their **migration network,** then they randomly select a *Recruiter*. **Rationale:** In accordance with Thailand's immigration law, labour migrants must enter Thailand with the appropriate identity and work document (typically a passport and work permit). The MMSNA (17), and other research in the Myanmar-Thailand corridor (16, 44), indicates that there are many different combinations of documents migrants may acquire at various stages of migration, including attempts to secure a passport and possibly a work permit (conditional on having a passport) before entering Thailand. In the legal migration channel (i.e., 'MOU' migration), recruitment agencies are the gatekeepers that process work permits (44). Individuals can choose to get passports on their own through the passport offices or can receive help from agencies in the passport application process before securing their work permit. In the MMSNA, some migrants expressed having a preference to migrate with some form of documentation (e.g., a passport or border pass – the latter addressed in future rules) or the 'MOU' way (passport *and* work permit) specifically. Overwhelmingly, according to the CHIME study and ILO reports on Myanmar-Thailand migration, the majority of Myanmar migrants still migrate to Thailand without any long term documentation (16, 18). Thus, this rule only assigns these pre-migration documentation plans (passport, work permit) to migrants with a preference for legal migration, otherwise the documentation plan stays empty currently.	**13a. Pre-transit documentation decision** IF *planDocumentation(t)* = empty THEN IF *preference = legal* THEN *planDocumentation(t) includes 'passport' with (probability = 0.15)* *planDocumentation(t) = 'passport' AND 'work permit' with (probability = 0.15)* *planDocumentation(t) stays empty with (probability = 0.7)* ELSE *planDocumentation(t) stays empty* END END **13b. Find Recruiter rule** IF *planDocumentation(t) includes 'work permit'* THEN IF *migrationNetwork does not include a Recruiter* THEN *randomly select recruiter id to add to migrationNetwork array* *accept offer* *populate plan(t) with recruiter offer* END END

14. Get pre-transit documentation rules

Planning-Migrants that have decided to get a passport need to go to either Magway or Yangon.

14a. Go to Magway or Yangon rule. If the *Planning-Migrant* only needs a passport and is in Rakhine or Magway they will go to the Magway passport office, but if they are in Bago or Yangon they will go to the Yangon passport office. If the *Migrant* needs a passport and a work permit, then they must go to Yangon.

14b. Respond to Myanmar-Doc-Broker offer. If a *Planning-Migrant* receives an unsolicited **offer** from a *Myanmar-Doc-Broker* to help with the passport application then they decide whether to accept the **offer** based on their current **wealth**, other **offers**, and **documentation plan**. See the Myanmar-Doc-Broker offer rule in Rule 31.

14c. Get Documents rule. Once a *Planning-Migrant* arrives at the passport office or recruiter agency and the processing time-steps have passed, they then get their documents. If a *Recruiter* or *Myanmar-Doc-Broker* is arranging the process then the *Migrant* always gets their documents, but if the *Migrant* is trying to get their passport alone there is a 25% chance they fail to get their passport. Either way, using a Myanmar-Doc-Broker speeds up the process for *Migrants*.If a Migrant fails to get a passport they still make a decision whether or not they will leave (Rule 15).

Rationale: A *Migrant* planning to get a work permit before migrating has to Yangon to complete the recruitment process. A *Migrant* that is only getting a passport can do this in major urban areas (Yangon or Magway in the model) and the model rule assumes that the *Migrant* will choose to go to whichever passport office is closest to their home area. Some of the qualitative narratives and network maps from the MMSNA described Myanmar based document brokers (unlicensed actors) that would work in the nearby vicinity of the passport offices to try and offer administrative support to individuals trying to apply for a passport in exchange for a fee. Migrants that chose to use these services explained that the process was too complicated or confusing for them to do alone and they preferred to pay to be sure they got the document and as quickly as possible (17). Because the fees paid to these agents were usually required up front (in cash) the rule includes a condition that the migrant has the available wealth on hand to cover the cost of the Myanmar-Doc-Broker's fees. These brokers were described by some respondents as essential service providers to ensure their passport application process was smooth, as quick as possible, and successful (17). The rule reflects an increased likelihood of success and speed for migrants that paid for extra administrative support from Myanmar-Doc-Brokers. The time-steps reflect the average processing time for these processes according to recent Verité led research on the MOU and other documentation processes (44).

14a. Go to Magway or Yangon rule

```
IF planDocumentation(t) includes 'passport'
THEN
        IF planDocumentation(t) includes 'work permit'
        THEN
                IF migrationNetwork(t) includes Recruiter
                THEN
                        Go to Recruiter's agency
                END
        ELSE
                IF home = Rakhine OR Magway
                THEN
                        Go to Magway passport office
                ELSE
                        Go to Yangon passport office
                END
        END
ELSE
        Leave decision (Rule 14)
END
```

14b. Respond to Myanmar-Doc-Broker offer

```
IF offer received from Myanmar-Doc-Broker AND documentation(t) =
empty
THEN
        IF migrationNetwork(t) does not include a Myanmar-Doc-Broker
        OR Recruiter
        THEN
                IF Myanmar-Doc-Broker fees < wealth(t)
                THEN
                        IF planDocumentation(t) = passport
                        THEN
                                accept offer with (probability =
                                0.75)
                                        migrationNetworkSize(t)
                                        =
                                        migrationNetworkSize(t-
                                        1) + 1
                                        migrationNetwork(t,
                                        migrationNetworkSize
                                        (t)) Myanmar-Doc-
                                        Broker's id
```

	reject offer with (probability = 0.25) ELSE *No change* END END END END **14c. Get documents rule** IF *at passport office* THEN IF *migrationNetwork(t) includes Myanmar-Doc-Broker* THEN *after 10 time-steps get passport* *documentationSize(t) = documentationSize(t-1) + 1* *documentation(t, documentationSize (t)) = passport* ELSE *after 17 time-steps get passport with (probability = 0.75)* *documentationSize(t) = documentationSize(t-1) + 1* *documentation(t, documentationSize (t)) = passport* *fail to get passport with (probability = 0.25)* *planDocumentation(t) = border pass* END ELSE **Leave decision** (Rule 15) END IF *at Recruiter agency* THEN *after 50 time-steps get passport* AND *work permit* *documentationSize(t) = documentationSize(t-1) + 2* *documentation(t, documentationSize (t)) = passport* AND *work permit* **Leave decision** (Rule 15) END

15. Leave decision A *Planning-Migrant* must make a final decision at the end of Sub-Model 2-B whether they want to leave. This is a probabilistic rule based partially on the **documentation** they have acquired. If they decide not to leave they walk **home** (pausing all other functions till they arrive home), update **state** to 'pre-migration', update **motivation** slightly decreased value of initialised **motivation** (and constrain motivation)**,** and, finally, they deactivate the most recent **migration** in their **migrations** array. **Rationale:** Like the end of Sub-Model 1, the assumption in this rule is that migrants that have made it through the process up till this point are more likely to continue than not. Migrants that have gone through the process and paid the cost for a passport and migrants that have a known employment option at destination are 15% more likely than migrants without a passport or employer plan to continue their migration.	**15. Leave decision** IF *documentation(t) includes passport* THEN *decide to leave with (probability = 0.95)* *decide not to leave with (probability = 0.05)* ELSE IF *planEmployer(t)* ≠ empty THEN *decide to leave with (probability = 0.95)* *decide not to leave with (probability = 0.05)* ELSE *decide to leave with (probability = 0.8)* *decide not to leave with (probability = 0.2)* END END IF *decides to leave* THEN *state(t) = transit* ELSE *walk home and pause all other function while walking home* *when at home state(t) = pre-migration* *deactivate most recent migration in the migrations array* *motivation(t) = initial motivation - 0.1* **Motivation constraint** (Rule 3c) END End time step

Sub-Model 3 – Transit

Narrative Overview

The primary agent that executes the process in Sub-Model 3 (see Figure 18 and Table 16) is a *Transit-Migrant*. A *Transit-Migrant's* goal is to arrive at their planned **destination** and to be offered **employment**. A *Transit-Migrant's* actions and decisions depend partly on any **offers** they have accepted, their **destination plan**, and their **preference**. Like Sub-Model 2, only certain steps are executed in each time-step and the whole process length depends on the time it takes to coordinate a **transport plan**, meet the conditions for departure, transit to **destination**, and find **employment**.

A *Transit-Migrant* makes a **transport** decision in this Sub-Model, but the final decision in this sub-model is made by the *Employer.* The *Employer* decides whether to **offer employment** in response to a *Transit-Migrant's* request. If a *Transit-Migrant* is offered employment then their **state** is updated to 'employed', but if they are not offered employment for over 100 time-steps then their **state** reverts to 'pre-migration'. An *Employed-Migrant* starts the next time-step in Sub-Model 4. A newly 'reverted' *Pre-migration-Migrant* walks **home**, decreases their **motivation**, and starts the next time-step back in Sub-Model 1.

Figure 18 depicts the Sub-Model 2 process annotated with the rule numbers that correspond to Table 16. Table 16 presents the Sub-Model 3 *Transit-Migrant* rules in the order they are executed. Again, like the previous sub-models, it is implicit in the Table 16 rules that a *Migrant's* **state** is 'transit'.

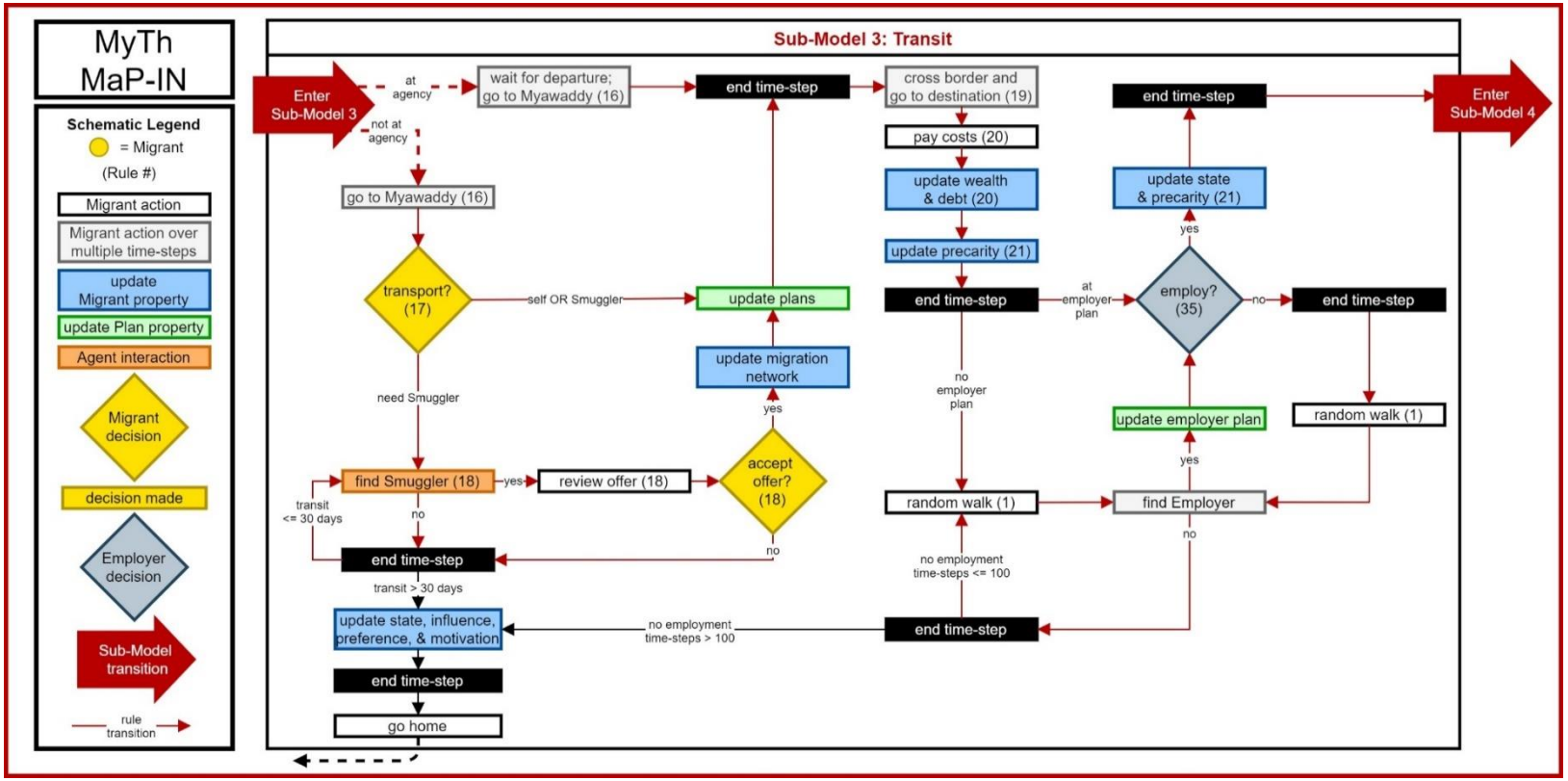


Figure 18. MyTh MaP-IN Sub-Model 3 schematic

Table 16. Sub-Model 3 rules

Rule description, rationale and calibration informed by McAlpine et. al.'s Myanmar-Thailand MMSNA study (17), University of Sussex's CHIME study (16), and the Myanmar Living Conditions survey (15).	**Model based rule** (IF-THEN or basic equation)
16. Go to Myawaddy rule All *Transit-Migrants* start Sub-Model 3 by going to the Myawaddy sub-area (next to the border crossings). A *Migrant* using a *Recruiter* waits at the agency in Yangon until their group of migrants is prompted to leave for Myawaddy. The departure is prompted once the total *Migrants* for a single *Employer* meet the agency's required minimum. See Rule 32. **Rationale:** Recruitment agencies work on *Employer* demand and recruit groups of migrants to transfer to destination and employer at the same time, via Myawaddy (44). Migrants that choose to go the MOU way through recruitment agencies are then subject to both the generic processing wait time (in previous Sub-Model 3) for all agencies and the agency specific wait time while they recruit fellow workers. Whereas migrants travelling outside of the MOU process do not have any delays to going to Myawaddy.	**16. Go to Myawaddy rule** IF *migrationNetwork(t) does not include a Recruiter* THEN IF *location(t) is not in Myawaddy* THEN *walk to Myawaddy* **Transport decision** (Rule 17) END ELSE *wait at agency till prompted to leave* (Intermediary Rule 33a) *walk to Myawaddy* End time step Next time-step: **Border crossing rule** (Rule 19) END

17. Transport decision A *Transit-Migrant* without a **transport plan** decides whether they will transport with or without a *Smuggler.* The **transport plan** decision depends on the *Migrant's* **destination plan** and whether they have a passport. If they decide to transport without a *Smuggler,* they must also decide which **border crossing** they will use. **Rationale:** There are many ways a migrant can cross the very long and porous border between Myanmar and Thailand (17). This model has simplified the border crossing options into three types: 1) unofficial crossing without a smuggler; 2) unofficial crossing with a smuggler; or 3) official crossing at the Thai immigration check-point. The choice to use a smuggler depends on the destination (how far a migrant needs to travel to get there) and their documentation (whether they have the rights to move about freely after crossing the border). Most migrants trying to get to Tak or Mae Sot would not pay for the services of a smuggler because it is easy to get to these destinations with or without documentation alone. However, a migrant trying to get as far as Bangkok or Phang Nga needs to travel a long distance through multiple document checkpoints (e.g., highway bus stops for passport checks of all bus passengers) and so without a document a migrant would need a smuggler's help.	**17. Transport decision** IF *planTransport(t)* = empty THEN IF *planDestination(t) = mae sot* OR *tak* THEN IF *documentation(t) includes 'passport'* THEN *planTransport(t) = own id* *planBorderCrossing(t) = 'official'* ELSE *planTransport(t) = own id* *planBorderCrossing(t) = 'official' with (probability = 0.3)* *planBorderCrossing(t) = 'unoffical1' with (probability = 0.7)* END ELSE IF *documentation(t) includes 'passport'* THEN *planTransport(t) = own id with (probability = 0.8)* *planBorderCrossing(t) = 'official' with (probability = 0.7)* *planBorderCrossing(t) = 'unofficial1' with (probability = 0.3)* *planTransport(t) = find smuggler with (probability = 0.2)* *no change to planBorderCrossing(t)* ELSE *planTransport(t) = find smuggler* *no change to planBorderCrossing(t)* END END END

18. Find Smuggler rules

18a. Request Smuggler offer rule. If a *Transit-Migrant* decides to transport with a *Smuggler* and does not currently have a **transport plan,** then they need to find a *Smuggler* in Myawaddy. They look for a *Smuggler* in their **vision** and request an **offer**. *Smugglers* are all located in a specific part of the Myawaddy sub-area near the 'unofficial2' border crossing that Smugglers use to take Migrants to Thailand. *Migrants* looking for a *Smuggler* know that this is the general area to find one. See the Smuggler offer rule in Rule 33.

If a *Transit-Migrant* has not accepted a *Smuggler* **offer** after 30 time-steps in 'transit' **state** they walk **home** (pausing all other functions till they arrive home), update **state** to 'pre-migration', update **motivation** slightly decreased value of initialised **motivation** (and constrain motivation)**,** and, finally, they deactivate the most recent **migration** in their **migrations** array.

18b. Review Smuggler offers rule. If a *Migrant* receives offers from a *Smuggler,* they decide whether to accept the *Smuggler's* **transport** and **border crossing** offer based on whether the *Smuggler's* **destination offer** matches the *Migrant's* **destination plan**. If multiple *Smugglers* meet these criteria in a single time-step the *Migrant* chooses the *Smuggler* with the lowest **fees**. If multiple *Smugglers* meet the lowest **fees** criteria, then the *Migrant* selects one of those *Smugglers* randomly.

Rationale: Because Myawaddy is a border-crossing town there are many smugglers and smuggler networks recruiting passengers in that area. This means that migrants, regardless of their destination plan, should be able to find a smuggler to arrange their transport. For simplicity in the model, all smugglers have been confined to a smaller zone of the Myawaddy area where it is assumed all migrants know to look for smugglers and always prefer lower fees.

18a. Find Smuggler rule

IF *planTransport(t) = findSmuggler*
THEN
    IF *duration since transport decision ≤ 30*
    THEN
        walk to Smuggler zone
        Random walk (Rule 1) *within that zone*
        request offer from Smuggler within vision
    END

    IF *duration since transport decision > 30*
    THEN
        walk home and pause all other function while walking home
        when at home state(t) = pre-migration
        motivation(t) = motivation(t-1) – 0.1
        deactivate most recent migration in the migrations array
        Motivation constraint (Rule 3c)
    END
ELSE
    Cross border and go to destination rule (Rule 19)
END

18b. Review Smuggler offers rule

IF *total Smuggler offers received = 1*
THEN
    IF *offerDestination = planDestination(t)*
    THEN
        migrationNetworkSize(t) = migrationNetworkSize(t-1) + 1
        migrationNetwork(t, migrationNetworkSize (t)) = smuggler's id
        planTransport(t) = smuggler's id
        planBorderCrossing(t) = 'unoffical2'
    END

ELSE IF *total Smuggler offers received > 1*
THEN
    IF *offerDestination = planDestination(t)*
    THEN
        filter to offers with lowest fees and randomly select one
        migrationNetworkSize(t) = migrationNetworkSize(t-1) + 1
        migrationNetwork(t, migrationNetworkSize (t)) = smuggler's id
        planTransport(t) = smuggler's id
        planBorderCrossing(t) = 'unoffical2'

	END ELSE *no change to planTransport(t) or planBorderCrossing(t)* END End time step
19. Cross border and go to destination rule **19a. Cross border and go to destination rule.** *Migrants* that are going to be transported by a *Smuggler* need to wait for that agent to prompt them to leave before they can leave Myawaddy. See the Departure rule (Rule 32). *Transit-Migrants* not using a *Smuggler* do not need to wait to leave Myawaddy. The 'waiting' period is the only distinction between the 19a IF/ELSE statement. **19b. Get border pass rule.** Any *Migrant* that goes through the 'official' border crossing without a passport collects a border pass during crossing. **Rationale:** Smugglers, like recruiters, maximise profits by taking groups of migrants to the same destination at one time. Thus, migrants must wait until their chosen smuggler has met their minimum passenger condition (enough to fit in a small number of vehicles and not too many to draw too much attention on illegal routes). Any migrant that is passing through an official immigration checkpoint without a passport needs to acquire a 'border pass'. These are temporary documents that gives migrants the right to enter Thailand (not work) and they are usually valid for 1 week but migrants can continuously renew them. Each pass costs 100 Thai Baht so any renewal would incur this cost.	**19a. Cross border and go to destination rule** IF *planTransport(t) = smuggler id* THEN *wait till prompted to depart* *go to 'unofficial2' border crossing and cross* IF *planEmployer(t) = empty* THEN *go to planDestination(t) location* ELSE *go to planEmployer(t) location* END ELSE IF *planTransport(t) = own id* OR *recruiter id* THEN *go to planBorderCrossing(t) and cross* IF *planEmployer(t) = empty* THEN *go to planDestination(t) location* ELSE *go to planEmployer(t) location* END **19b. Get border pass rule** IF *borderCrossing(t) = 'official'* AND *documentation(t) does not include 'passport'* THEN *documentationSize(t) =documentationSize(t-1) + 1* *documents(t,documentationSize(t)) = border pass* END

20. Migration costs rules

Key parameter used in this rule:
costDailyTransit *= 0.001 (100 THB)*
costDocTransit *= .01 IF a Migrant went to Yangon/Magway for passport or work permit, otherwise* ***costDocTransit*** *= 0*
costFailedPassport *= .01 IF a Migrant unsuccessfully attempted to get a passport, otherwise* ***costFailedPassport*** *= 0*

20a. Pay migration costs rule. For simplicity's sake in the model, the migration **costs** are summed and paid when a Migrant arrives at **destination** (or **employer** if they are going directly to a planned **employer**). The way these costs are paid (i.e., deducted **wealth**, increased **debt to family**, or increased **debt to industry**) is determined by the wealth the *Migrant* and their family have at the time-step they leave home. The possible applicable **costs**, include:

- Cost of **transit**
- Cost of **documentation**
- Cost of *Intermediary* **fees**

20b. Acquired migration debt rule. Instead of constraining **wealth** and simply 'discarding' and negative value from the agent's **wealth** property (as in Sub-Model 1), **wealth** is still constrained to 0 but any negative **wealth** is assigned to either their **debtFamily** or **debtIndustry** property. After the negative value is moved to debt then wealth is constrained.

20c. Recurring border pass cost. Border pass documents have a randomly set expiration date but this is a proxy for when a *Migrant* decides to 'stop renewing'. Border passes must be renewed every 7 days and thus this is one migration cost that is recurring and repeats until the document expires or until the *Migrant* decides to return **home**.

Rationale: In the MMSNA analysis, migrants identified family actor network nodes as the individuals who often financed their migrations or that they financed migration by taking on debt to the intermediaries coordinating their migration or first employers at destination (sometimes the debt was transferred from the intermediaries to the employer). This rule assumes that *Migrants* are always partial to being indebted to family before 'industry' (i.e., intermediaries and employers), because family members less frequently charge interest and industry almost always does. But, if the migrant's nuclear family does not have enough excess wealth (above 0.2 in this rule) to pay for the migration costs then a migrant is forced to take on debt to 'industry'. For simplicity and due to limited data, this rule does not consider that migrants might handle finance differently based on factors other than family absolute wealth.

20a. Migration costs rule

*costTransit = durationTransit(t) * costDailyTransit + costDocTransit*
costDocumentation = sum of costs in documentation(t) array + costFailedPassport
costFees = sum of fees of Intermediaries in migrationNetwork(t)

IF *Migrant has arrived at planned destination*
THEN
    cost = costTransit + costDocumentation + costFees
    wealth(t) = wealth(t-1) - cost
    Acquired migration debt rule (Rule 20b)
END

20b. Acquired migration debt rule

IF *wealth(t) < 0*
THEN
    IF *nuclearFamilyWealth(time step of leave decision) > .2*
    THEN
        debtFamily(t) = |wealth(t)|
        debtIndustry(t) = 0
    ELSE
        debtFamily(t) = 0
        debtIndustry(t) = |wealth(t)|
    END
ELSE
    debtFamily(t) = 0
    debtIndustry(t) = 0
END
End time-step
Wealth constraint (Rule 2d)

20c. Recurring border pass cost

IF *state = transit OR employed*
THEN
    IF *border pass is not expired*
    THEN
        Every 7 time-steps repeat:
            wealth(t) = wealth(t-1) – borderPass cost
            Wealth constraint (Rule 2d)
    END
END

21. Livelihood pressure and precarity rules

21a. Livelihood pressure rule. This is a multi-dimensional indicator of financial pressure using current debt, family wealth, and wages.

21b. Precarity rule. This is a multidimensional indicator of precarity using **livelihood pressure**, current documentation and location, and destination knowledge and support.

*Note: Only one indicator from each of the 1-8 groupings can count toward a single score. The total possible scores can range from 0-1. (e.g., a migrant that meets the criteria for 1 . . .8 gets the highest possible score of 1, a Migrant could meet none of the indicator criteria and thus have the lowest possible score of 0).

Rationale: Individual precarity (or 'hyper'-precarity) is a multi-dimensional outcome formalized in the model. The domain justification for the choice of this outcome and included indicators is in Section A.7.13.

21a. Livelihood score rule

livelihoodPressure(t) = sum of livelihood pressure indicators that apply

21b. Precarity score rule

precarity(t) = sum of all indicators that are TRUE

Livelihood Pressure	1. debtFamily(t) > wealth(t)	0.1
	2. debtIndustry(t) > 0	0.2
	3. familyWealth is in lowest 25% of households	0.1
	4. monthlyWages < .09 (i.e., below minimum wage)	0.1
Legal status	5a. no documents and in Mae Sot or Tak	0.1
	5b. no work permit and in Bangkok or Phang Nga	0.2
Knowledge & support at destination	6. this is the migrant's first migration	0.1
	7. no family at destination	0.1
	8. no viable, attractive alternative jobs (i.e., vacancy and higher wages and required documents satisfied)	0.1

22. Find employer or go to employer rules If a *Transit-Migrant* is at their planned **destination** but does not have an **employer plan** or was 'rejected' by their original **employer plan,** then their goal is to find an **employer**. First, they random walk within their destination and look for an *Employer* and request an offer from any *Employer* they find. See the Employer offer rule in Rule 34. **Rationale:** The MMSNA indicated that migrants who arrived at destination without a work plan or known employer would ask around at possible employers to see if there are any vacancies. In some cases, migrants explained that employers might require the migrant have a passport or workPermit (for that employer specifically – i.e., came through MOU channel) to work there). In those cases, the migrant was never offered employment. After extended periods of unemployment at destination a migrant is forced to return home due to the high cost of surviving at destination.	**22. Find employer or go to employer rule** IF *planEmployer(t)* = empty THEN IF *duration at destination* ≤ 100 THEN **Random walk rule** (Rule 1) *within destination sub-area* IF *any Employer is within Migrant's vision* THEN *request employment offer* ELSE *no change* END ELSE *walk home and pause all other function while walking home* *when at home state(t) = pre-migration* *motivation(t) = motivation(t-1) – 0.1* *deactivate most recent migration in the migrations array* **Motivation constraint** (Rule 3c) END ELSE IF *at planEmployer(t)* AND *currentEmployer(t)* = empty THEN *request employment offer* END END **End time-step**
23. Accept employment rule If a *Transit-Migrant* receives an **employment offer** they accept the offer and update their **state** to 'employed', add the *Employer* to their **migration network** and assign the *Employer* as their **current employer.** **Rationale:** This model assumes that, in this corridor and for this population of migrants, any migrant at destination without a source of income will accept any offer they receive.	**23. Accept employment rule** IF *Employer offer received* THEN *accept offer* *state(t) = employed* *currentEmployer = Employer's id* *migrationNetworkSize(t) = migrationNetworkSize(t-1) + 1* *migrationNetworkSize(t, migrationNetworkSize (t)) = Employer's id* END **End time-step**

Sub-Model 4 – Employment

Narrative Overview

The primary agent that executes the process in Sub-Model 4 (see Figure 19 and Table 17) is an *Employed-Migrant*. *Employed-Migrants* are no longer executing decisions and steps to migrate or to find work as they have now achieved these goals. An *Employed-Migrant* completes 6-month **work** cycles, during which they experience a **pay day** every month. On non-paydays, a *Migrant* might invite other family members to migrate, acquire new **documentation** through a *Thai-Doc-Broker*, or decide to return **home** 'early'**.** At the end of each **work** cycle, a *Migrant* is forced to assess their situation to decide if they will return **home** or continue working.

Figure 19 depicts the Sub-Model 2 process annotated with the rule numbers that correspond to Table 17. Figure 19 depicts the Sub-Model 4 process annotated with the rule numbers. Table 17 presents the **Sub-Model 3** *Employed-Migrant* agent rules in the order they are executed. Again, like the previous sub-models, it is implicit in Table 17 that a *Migrant* agent's **state** is 'employed'

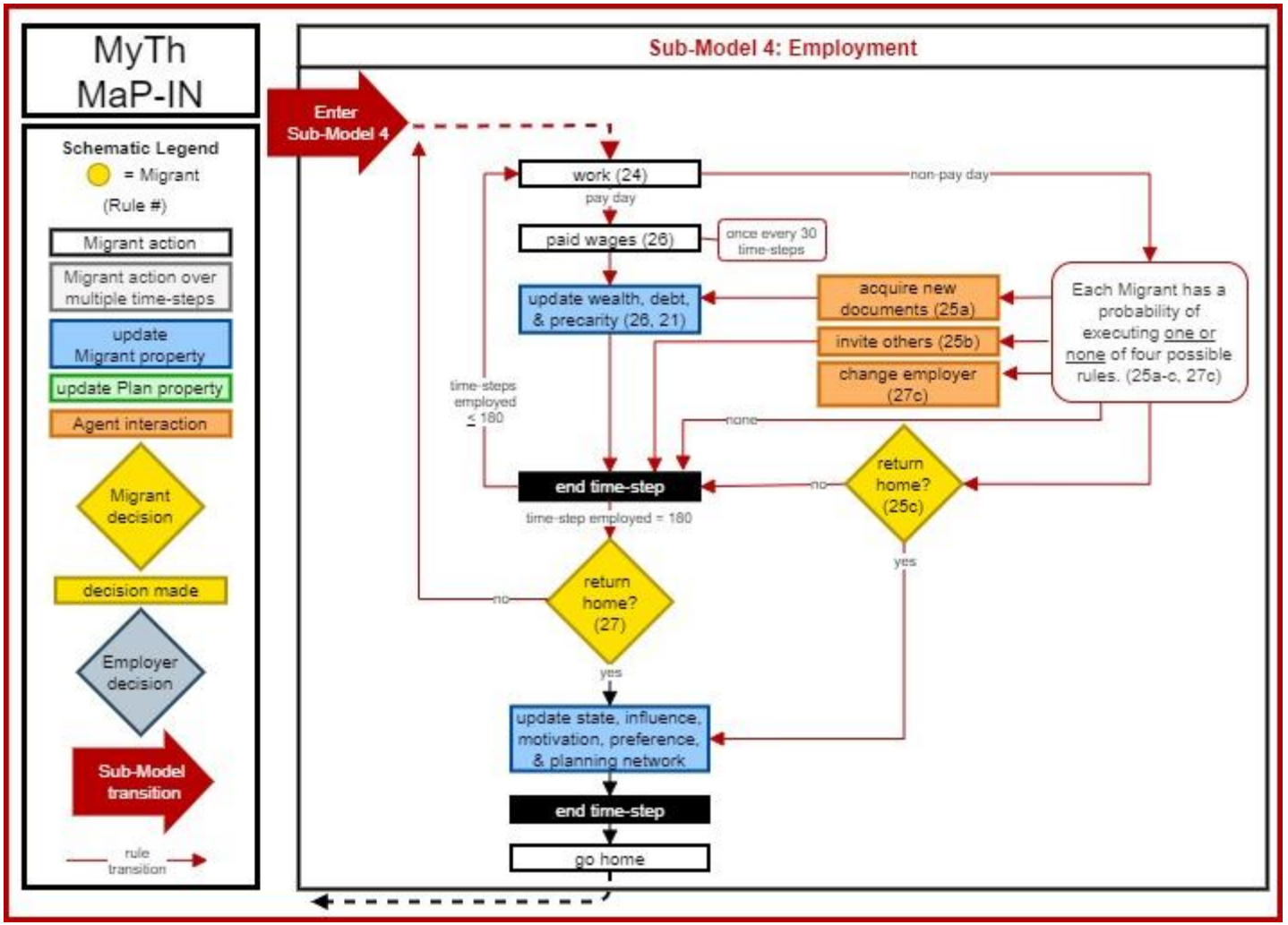


Figure 19. MyTh MaP-IN Sub-Model 4 schematic

Table 17. Sub-Model 4 rules

Rule description, rationale and calibration informed by McAlpine et. al.'s Myanmar-Thailand MMSNA study (17), University of Sussex's CHIME study (16), and the Myanmar Living Conditions survey (15).	**Model based rule** (IF-THEN or basic equation)
<u>24. Work rules</u> **24a. Work rule** An *Employed-Migrant* works for 180 time-steps (i.e., 6 months). Once a month they experience a **pay day** like the pattern of the **wealth fluctuation** in Sub-Model 1. Otherwise, they may complete other actions while at destination (Rule 26) during their non pay days. N.B. The % symbol in this rule is not being used to represent a percentage, but instead it is a common programming notation for the modulo operator (i.e., returns the remainder left over when one operand is divided by a second operand). **24b. Solicited offer response rule.** If an *Employed-Migrant* receives a request for an offer from a *Planning-Migrant* (Rule 9) then they respond with an offer 70% of the time. **Rationale:** In an aim of keeping the model simple but true to the research question, migrants work for set cycles of 6-months, with opportunity to execute one of a few typical 'changes' at destination. Migrants can, although rarely, choose to go home before the end of 6-motnths of working. This was reflected in the MMSNA where most migrants stayed in first employment for at least 3-6 months to earn livelihood or pay off migration expenses before attempting to change employers, migrate onward, or return home. Most migrants stay on average between 2-3 years in Thailand so for this model we assumed 6-months without a required decision point was an accurate reflection of destination dynamics (16, 18). Additionally, migrants can invite family from Myanmar, a typical trend in many low-wage labour migration corridors and evident in the MMSNA given most migrants were invited by social contacts at destination. Finally, migrants that are undocumented can also attempt to secure documentation at destination to decrease precarity or increase earning power, both of which were described as motivation for pursuing new documents in the MMSNA. Migrants also mentioned fearing deportation and wanting to secure documents through their employer or local Thai brokers (17).	**24a. Work rule** IF *durationEmployed(t) ≠ 180 (or multiple of 180)* THEN IF *(current timestep – monthlyWealthFluctuationOffset)%30 != 0* THEN IF *preference = legal* THEN **Request Thai-Doc-Broker offer rule** (Rule 25a) *with (probability = 0.08)* **Invite family rule** (Rule 25b) *with (probability = 0.01)* **Return home early rule** (Rule 25c) *with (probability = 0.01)* *Skip all rules with (probability = 0.90)* ELSE IF *preference = social* OR *family* **Request Thai-Doc-Broker offer** (Rule 25a below) *with (probability = 0.01)* **Invite family rule** (Rule 25b below) *with (probability = 0.08)* **Return home early rule** (Rule 25c below) *with (probability = 0.01)* *Skip all rules with (probability = 0.90)* ELSE **Request Thai-Doc-Broker offer** (Rule 25a) *with (probability = 0.01)* **Invite family rule** (Rule 25b) *with (probability = 0.02)* **Return home early rule** (Rule 25c) *with (probability = 0.01)* **Change employer** (Rule 27c) with *(probability = 0.01)* *Skip all rules with probability = 0.95* END ELSE **Payday rules** (Rule 26) END ELSE **Return home decision** (Rule 27) END **24b. Solicited offer response rule:** IF *received request from Planning-Migrant*

	THEN *make offer with (probability = 0.7)* *do not make offer with (probability = 0.3)* END

25. Non pay day actions rule

On a non-payday time-step, an *Employed-Migrant* might execute one of three possible actions below based on the probabilities and conditions in Rule 24.

25a. Request Thai-Doc-Broker offer rule. If an *Employed-Migrant* does not have a valid work permit, then they might request help from a *Thai-Doc-Broker* to acquire new **documentation**. See the *Thai-Doc-Broker actions* in Rule 35b.

25b. Invite family rule. If an *Employed-Migrant* has low or medium precarity then they invite their extended family member with the highest **motivation** to migrate. See *Pre-migration-Migrant* response is in Rule 5+6.

25c. Return home rule. If an *Employed-Migrant* does not have a valid work permit or has not satisfied their migration preferences, they have a higher probability of deciding to return **home** before the end of the 6-month work cycle.

An Employed-Migrant will only do one or none of these actions (25 b-d) on a non-payday and none of them on a payday.

Rationale 25a: A migrant without a work permit that is presented an opportunity to secure documentation will likely accept and for this model, given the low probability of this rule executing, migrants will always accept this potential offer for documents. However, the MMSNA qualitative narratives about the exchanged between migrants at destination and Thai-based document brokers indicated that these can be high risk transactions because migrants pay the full cost up front with no guarantee of service and it is increasingly difficult to secure work permits outside of the Myanmar-side initiated MOU process (17). Therefore, distinct from the Myanmar-Document-Broker transactions, Thai-Doc-Brokers do not always deliver on the services (they do according to their 'completion rate') but do always charge the costs up front.

Rationale 25b: Myanmar-Thailand migration is often facilitated by social contacts, usually family at destination (16). This rule, like the unsolicited family offers rules in Sub-Model 2, reflects the trend in Myanmar migrants in Thailand to create opportunities for their kin abroad. In most of the

25a. Request Thai-Doc-Broker offer rule

IF *documentation(t) does not include a work permit*
THEN
    possibleThaiDocBrokers = Thai-Doc-Brokers in planningNetwork(t) OR *currentEmployer's links*
    randomly select one Thai-Doc-Broker from possibleThaiDocBrokers

    migrationNetworkSize(t) = migrationNetworkSize(t-1) + 1
    migrationNetworkSize(t, migrationNetworkSize (t)) = Thai-Doc-Broker's id
    wealth(t) = wealth(t-1) – Thai-Doc-Broker's fees - docCosts

    receive work permit with (probability = Thai-Doc-Broker's completionRate)
    documentationSize(t) = documentationSize(t-1) +1
    documentationSize (t, documentationSize(t)) = work permit

    fail to receive work permit with (probability = 1- Thai-Doc-Broker's completionRate)

    Debt rule (Rule 26c)
    Wealth constraint rule (Rule 2d)
    Update precarity rule (Rule 21)
ELSE
    no change to migrationNetwork(t), documentation(t), debt(t), or precarity(t)
END
End time-step

25b. Invite family rule

IF *precarity(t) < .8*
THEN
    IF *currentEmployer's currentEmployees < maximumEmployees*
    THEN
        make offer to extended family Pre-migration-Migrant with highest motivation(t)
        offerDestination = destination
        offerEmployer = currentEmployer
    ELSE
        make offer to extended family Pre-migration-Migrant with highest motivation(t) with probability = 0.5
        offerDestination = destination
        offerEmployer = empty

        make no offer with probability = 0.5
    END

interviews, family proactively making invitations was an indication of their own security at destination and these invitations sometimes included employment offers through the destination-based family's current employment (17). **Rationale 25c:** while most migrants will aim to stay at destination to pay off costs and achieve livelihood goals, in some cases migrants may have reason to return home early. Two examples discussed in the qualitative date are migrants being forced to return home because they are deported (i.e., found out for not having valid work documents matching their current employer) or choosing to go home because they are not satisfied with their outcome. In the model, we have used unsatisfied preferences related to workplace as a proxy for motivation to return home early. Other indicators of workplace satisfaction related to profit from earnings are considered in the 6-month return home decision, not in the early decision here.	ELSE *do not invite family* END **End time-step** **25c. Return home rule** IF *documentation does not include a work permit* THEN *return home with (probability = 0.2)* *keep working with (probability = 0.8)* ELSE IF (*preference = sector* OR *wages* OR *proximity*) AND *preference is not satisfied* THEN *return home with (probability = 0.2)* *keep working with (probability = 0.8)* ELSE *no change* END **End time-step**

26. Pay day rules

Two global parameters are used in these rules:

debtPayRate *= 0.5*

interestRate *= 1.07*

26a. Wages and overtime rule. The wages a *Migrant* is owed **(wagesOwed)** are a combination of their monthly wage and any overtime they are paid.

26b. Deductions and paid wages rule. If a *Migrant* is in debt to the industry **(debtIndustry)**, they are forced to forfeit 50% of their wages to pay off debt (**debtPayRate**). Debt is increased by 7% fixed interest every payday. All *Employed-Migrants*, regardless of debt, may also experience other unlawful deductions from their wages (**monthlyDeductionRate**). These two forms of deductions together (**deductionRate**) are applied to a Migrants owed wages to determine their paid wages (**wagesReceived**). Final received wages get added to current wealth.

26c. Debt rule. Like the costs of migration (Sub-Model 3), any negative wealth is transferred to debt, in this case **debt to industry**. If a *Migrant's* **debtIndustry** increases they also then update their livelihood pressure and precarity. At the end of this rule wealth is constrained between 0-1.

26d. Industry debt payment. The paid debt is removed from the *Migrant's* current **debtIndustry.**

26e. Industry debt constraint. The paid debt is removed from the *Migrant's* current **debtIndustry.**

Rationale: The payday rule considers the many debits and credits that determine migrants' final profit from work, including, wages, deductions, paying off debt, and increasing debts. Migrants often experience 'wage theft' in multiple forms that can amount to exploitative employment practices and even debt bondage in the more sever cases (45). In the MMSNA, 27% of respondents missed some form of overtime pay, 56% of respondents were paid below minimum wage, and 58% experienced unlawful deductions from wages (17). Often these multiple forms of wage theft compound and create significant losses to migrants expected earnings. The MMSNA informed the types and frequencies of these different forms of wage losses.

26a. Wages and overtime rule

IF *timestep is payday*
THEN
overtimeOwed(t) = overtimeHours overtimeHourlyWage*
wagesOwed(t) = monthlyWage(t) + overtimeOwed(t)
Deduction and paid wages rule (Rule 26b)
END

26b. Deductions and paid wages rule

IF *debtIndustry(t-1) > 0*
THEN
*debtIndustry(t) = debtIndustry(t-1)*interestRate – wagesOwed(t)*debtPayRate*
deductionRate(t) = monthlyDeductionRate(t) + debtPayRate
Update livelihood pressure and precarity rule (Rule 24)
ELSE
deductionRate(t) = monthlyDeductionRate(t)
END

*wagesReceived(t) = (wagesOwed(t)*deductionRate(t))/2*
wealth(t) = wealth(t-1) + wagesReceived(t)

26c. Debt rule

IF *wealth(t) < 0*
THEN
add value below 0 to debtIndustry(t)
Update livelihood pressure and precarity rules (Rule 24)
ELSE
no change to debtIndustry(t), livelihoodPressure(t), or precarity(t)
END

Wealth constraint rule (Rule 2d)

26d. Industry debt payment and interest rule

*debtIndustry(t) = debtIndustry(t-1) – wagesOwed (t)*debtRate*

26e. Industry debt constraint: *debtIndustry(t)* = MIN[1,MAX[0,debtIndustry(t)]

27. Return home decision

A global parameter used in this rule is:
savingsGoal = 3*monthlyWages

27a. Leave job decision. After a 6-month work cycle, an *Employed-Migrant* must decide whether to keep working at their current employer, go to a new employer, or return home. They make this decision based on their current debt, wealth, and, in some cases, whether their current migration is meeting their preference.

27b. Return home decision.

27c. Find new Employer
If a *Migrant* decides to go to a new *Employer.* They identify any *Employer* that either:

- Pays higher **wages** than their **current employer**; or
- Satisfies their **sector** or **wages preferences**

If they identify an *Employer*, the *Employer* must meet these 3 criteria for the *Migrant* to change *Employers*:

- Be in the *Migrant's* **destination** sub-area
- Be satisfied with the *Migrant's* documentation (i.e., *Migrant's* **documentation** satisfies *Employer's* **requiredDocuments**) docs match required docs
- Have vacancy (i.e., **currentEmployees**(t) < **maximumEmployees**)

If the *Migrant* had a work permit at their previous *Employer* but is changing *Employer* then they now loose their work permit. If the Migrant does not identify an Employer or the Employer does not meet the criteria, then the Migrant instead returns home.

Rationale: After 6-moonths, all migrant agents in the model assess their situation. Migrants consider their debt to industry, workplace preferences, wealth improvements (or losses), and outstanding debt to family they will need to pay back on return. Most migrants have the base aim of paying the costs of their migration and returning home with some profit which we have assumed to be at least 3-months Thai minimum wage (0.027). Migrants that are in debt to industry cannot leave their current employer as it is assumed the debt it to that employer or associates and is tying the migrant to that workplace.

27a. Leave job decision

IF *durationEmployed(t) = 180 (or multiple of 180)*

THEN
IF *debtIndustry(t) > 0*
THEN
stay at current employer
ELSE
IF *preference = sector OR wages AND is not satisfied*
THEN
IF *wealth(t) > (savingsGoal + debtFamily)*
THEN
stay at current employer with (probability = 0.1)
Find new employer (Rule 27c) *that meets preference condition with (probability = 0.1)*
Return home decision (Rule 27b) *with (probability = 0.8)*
ELSE
stay at current employer with (probability = 0.1)
Find new employer (Rule 27c) *that meets preference condition with (probability = 0.6)*
Return home decision (Rule 27b) *with (probability = 0.3)*
END
ELSE
IF *wealth(t) > (savingsGoal + debtFamily)*
THEN
stay at current employer with (probability = 0.5)
Return home decision (Rule 27b) *with (probability = 0.5)*
ELSE
stay at current employer with (probability = 0.3)
Find new employer (Rule 27c) *that pays higher wages with (probability = 0.6)*
Return home decision (Rule 27b) *with (probability = 0.1)*
END
END
END
END

27b. Return home decision.
IF *decided to return home*

Migrants that have not made the minimum 3-month profit are more likely to decide to find a new employer that pays higher wages, and for this with an unsatisfied workplace preference they will look for an employer that satisfies that preference. In the MMSNA study, 51% of respondents had more than one employer actor in their migration network indicating a frequency with which Myanmar migrant change employers in Thailand despite the regularised formal channels including increased barriers to trying to change employers. Many migrants described learning about better or higher paying employers or more 'comfortable' jobs with better hours after arriving and becoming more familiar with the destination (17).	*THEN* *walk home and pause all other function while walking home* *when at home state(t) = pre-migration* *deactivate most recent migration in the migrations array* *pay off socialDebt from wealth* *disperse remaining wealth equally across nuclear family, including themselves* IF *wealth(t) > (savingsGoal + debtFamily)* THEN *influence(t) = influence * 1.25* **Influence constraint** (Rule 6b) ELSE *planningNetwork(t)* = empty END END **27c. Find new Employer** IF *decides to find new employer* THEN IF *any employer in destination meets the Migrant's selection criteria* (i.e., higher wages OR satisfies preference) THEN IF *Migrant's documentation(t) satisfies Employer's requiredDocumentation* THEN IF *Employer's currentEmployees(t) < maximumEmployees* THEN *currentEmployer(t) = new employer's id* ELSE *walk home and pause all other function while walking home* *when at home state(t) = pre-migration* *deactivate most recent migration in the migrations array* IF *wealth(t) > (savingsGoal + debtFamily)* THEN *influence(t) = influence * 1.25* **Influence constraint** (Rule 6b) ELSE *planningNetwork(t)* = empty END

	END END END END IF *migrant changes employer* THEN IF *documentation(t) includes 'work permit'* THEN *remove work permit* END END

Sub-Models 1-4 – Intermediary and Employer rules

Figure 20 and Table 18 describe the *Intermediary* and *Employer* agent processes and rules that are executed across Sub-Models 1-4. These rules were referenced in the other sub-model figures and tables.

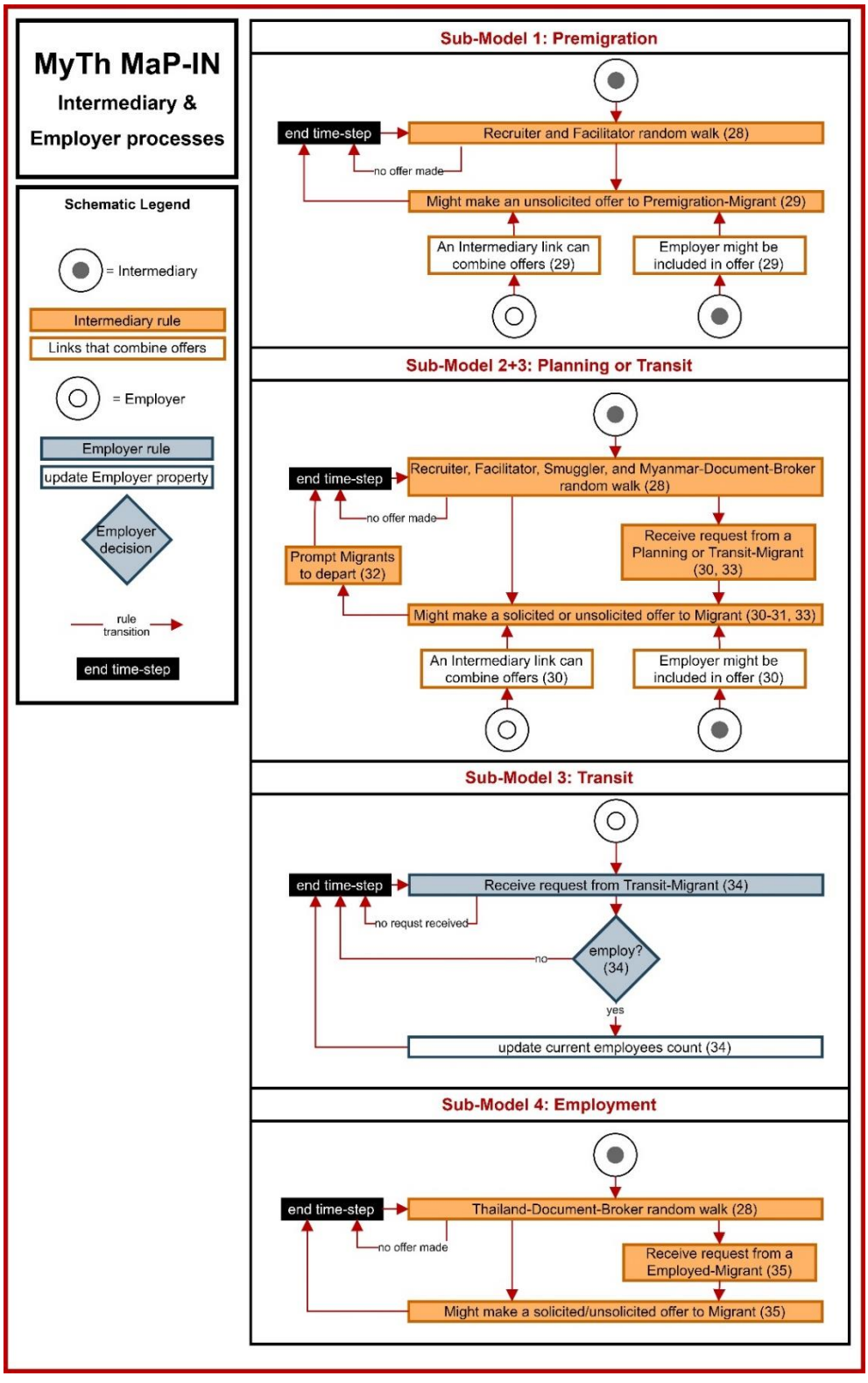
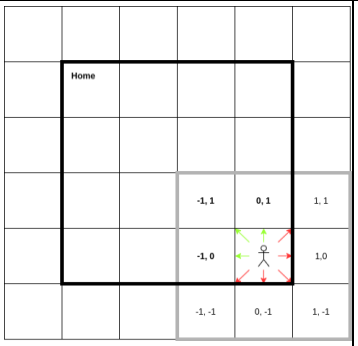


Figure 20. MyTh MaP-IN Sub-Models 1-4 Intermediary and Employer schematic

Table 18. Sub-Model 1-4 Intermediary and Employer rules

Rule description, rationale and calibration informed by McAlpine et. al.'s Myanmar-Thailand MMSNA study (17), University of Sussex's CHIME study (16), and the Myanmar Living Conditions survey (15).	**Model based rule** (IF-THEN or basic equation)
28. Intermediary movement rules Same as *Migrant* **Random walk rule** (Rule 1). Note: Smugglers only are also constrained to a smaller area within Myawaddy near their border crossing to allow Migrants looking for a Smuggler to do so within a smaller geographic area.  **Rationale:** This rule allows for similar chance encounters as between migrant agents. Non-spatially conditioned interactions take place through agent links and networks (described in other rules). In the MMSNA qualitative narratives, migrants described meeting intermediaries in their communities, in transit, or nearby points of interest. Intermediaries' location assignments are informed by the typical locations and processes associated with specific intermediary types.	**28a. Intermediary random walk rule** Same as 1a, but for agent = intermediary. **28b. Intermediary random walk constraint** Same as 1b, but for agent = intermediary.
29. Recruiter and Facilitator unsolicited offer rule Some *Pre-migration-Migrants* receive an **offer** to migrate from an *Intermediary* agent. If a *Pre-migration-Migrant* is within a *Recruiter* or *Facilitator's* **vision**, then the *Intermediary* makes an unsolicited **offer** to the *Pre-migration-Migrant* 70% of the time. See *Pre-migration-Migrant* response is in Rules 5 and 6. N.B. A *Facilitator* makes at least one offer with their own offer properties and possibly additional combined offers using the offer properties of agents in their **links**. The *Recruiter,* who may have multiple combinations of offer properties, always tries to make an offer that matches the Migrant's preference if possible and otherwise	**29. Recruiter and Facilitator unsolicited offer rule** IF *agent = Recruiter* or *Facilitator* THEN IF *Pre-migration-Migrant is within vision* THEN *make offers to Pre-migration-Migrant with (probability = 0.7)* *do not make offers with (probability = 0.3)* END END

selects randomly from possible offer properties. For example, if the *Migrant's* preference is to go where family is then if the *Recruiter* has a link to an *Employer* in the same destination as the *Migrant's* family then the *Recruiter* makes this offer (whether directly or through the *Facilitator*). If not, then the *Recruiter* makes one offer with a randomly selected *Employer* and matching destination. **Rationale:** The MMSNA indicated that some intermediaries proactively recruit individuals to migrate and offer to arrange their migration and in some cases employment. The typical 'proactive' intermediaries that might make unsolicited offers the early stage of the migration planning, according to the MMSNA, are facilitators and recruiters which are more often involved in high-level migration planning not just specific migration steps (e.g., documentation or transport) that are more typically solicited offers (17).	
30. Solicited offer response rules See request offer rule in Rule 9. **30a. Solicited intermediary offer response rule** If an *Intermediary* receives a request from a *Planning-Migrant* they respond with an **offer** 90% of the time. **30a. Solicited intermediary offer response rule** If an *Employed-Migrant* receives a request from a *Planning-Migrant* they respond with an **offer** 70% of the time. All other *Migrant* types (i.e., *pre-migration, planning, transit, returned*) do not make *offers*. N.B. An agent makes at least one offer (i.e., one set of offer properties) and possibly additional combined offers using the offer properties of agents in their **links,** in the case of intermediaries, or migration network, in the case of migrant agents. **Rationale:** Intermediaries are proactively looking for and responding to clients. This model assumes that any active intermediary is unlikely to turn down the opportunity for a customer. Meanwhile, migrants at destination often take on risk, costs, or burdens to help another family member migrate and often without direct financial gain or incentive (17).	**30a. Solicited intermediary offer response rule** IF *agent = Recruiter* or *Facilitator* THEN IF *request received from Planning-Migrant* THEN *make offers to Pre-migration-Migrant with (probability = 0.9)* *do not make offers with (probability = 0.1)* END END **30b. Solicited migrant offer response rule** IF *agent = Migrant* AND *state = employed* THEN END
31. Myanmar-Document Brokers unsolicited offer rule *Myanmar-Document-Brokers* stay in the vicinity surrounding the passport offices looking for *Migrant* agents to **offer** passport help to.	**31. Myanmar-Document Brokers unsolicited offer rule** IF *agent = Myanmar-Doc-Broker* THEN IF *Planning-Migrant is within vision*

They always make an offer to any *Migrant* that comes within their **vision.** **Rationale:** The egocentric network data indicated that some 'brokers' work specifically in the documentation process, on both the Myanmar and Thai side of the corridor (17). Because work permits are arranged by recruitment agencies, the Myanmar side document brokers most often coordinated the passport process for individuals that were unable to navigate the process by themselves. These actors took fees up front for their help and often guaranteed successful application. The qualitative narratives described these actors as being recognizable and available around the passport offices (17).	THEN *make offerDocumentation = passport to Planning-Migrant* END END
<u>32. Departure rules</u> **32a. Recruiter departure rule** *Recruiters* do not send *Migrants* to Myawaddy until they have a 'large enough' group to send to a singular employer. **32b. Smuggler departure rule** *Smugglers* do not take *Migrants* to their destination (or employer) until they have a 'large enough' group of passengers for the transit. **Rationale:** Both recruiter and smuggler agents work on 'economies of scale', which means they look to coordinate for a group of migrants to maximise profits but also minimise administrative work (17, 44). In the case of recruiters, they are also often meeting the demand of an employer. To simplify the attributes we have assigned to employers, the model assumes that recruitment agencies are often recruiting similar 'bulk' numbers of workers for their employer clients.	**32a. Recruiter Yangon departure rule** IF *class = agency* THEN IF *agency's total recruited migrants with the same planEmployer(t) is ≥ agency's recruitMinimum* THEN *send those recruits to Myawaddy* ELSE *Migrants stay at agency* END END **32b. Smuggler departure rule** IF *agent = smuggler* THEN IF *smuggler's total passengers with the same planDestination(t) ≥ passengerMinimum* THEN *send all Migrants to destination with that planDestination(t) to destination* ELSE *Migrants stay in Myawaddy* END END
<u>33. Smuggler solicited offer rule</u> If a *Smuggler* receives a request for a **transport offer** and they coordinate transport to the **destination** the *Migrant* is planning to go to then they always make an offer.	**33. Smuggler solicited offer rule** IF *agent = smuggler* THEN IF *request received* THEN

Rationale: The MMSNA indicated that smugglers were readily available in Myawaddy to coordinate transport on specific routes to popular migrant destinations. Smugglers would make offers to any migrant customers wanting to travel on said routes regardless of other attributes about the migrant (17). Even the costs of this transaction could be covered up front or often transferred as debt to employers or family upon arrival(17).	IF *offerDestination = Migrant's planDestination(t)* THEN *make offerTransport = smuggler's id and offerBorderCrossing = 'unofficial2'* END END END
34. Employer response to request rule Once a *Transit-Migrant* has arrived at the *location* of their *employer-plan* they then need to decide whether to take the employment. This decision is first contingent on the *employer* still having a *vacancy* and on the *employer's document-requirements* matching the *documents* the *Migrant* has acquired.	**34. Employer response to request rule** IF *agent = employer* THEN IF *request received for Transit-Migrant* THEN IF *currentEmployees < maximumEmployees* THEN IF *Migrant's documentation(t) satisfies requiredDocumentation* THEN *Make offerEmployment = employer's id with (probability = 0.9)* *do not make employment offer with (probability = 0.1)* END END END END
35. Thai-Doc-Broker offers **35a. Unsolicited offer** *Thai-Doc-Brokers* make **offers** to help with **documents** to any *Migrant* (regardless of state) that comes into their **vision.** **35b. Solicited offer** *Thai-Doc-Brokers* make **offers** to help with **documents** to any *Migrant* (regardless of state) that requests an **offer.** **Rationale:** Like Myanmar based document brokers and other intermediaries, the Thai based document brokers are incentivised to make profit and therefore do not turn down possible customers. These brokers make offers through direct contact but also through requests from migrants that know about their services from previous interactions or from links to the migrant's employer (17).	**35a. Thai-Doc-Broker unsolicited offer** IF *agent = Thai-Doc-Broker* THEN IF *Employed or Transit Migrant is within vision* THEN *make offer* *Migrant's planningNetworkSize(t) = planningNetworkSize(t-1) + 1* *Migrant's planningNetwork(t, planningNetworkSize(t)) = id of Thai-Doc-Broker* END END **35b. Thai-Doc-Broker solicited offer** IF *agent = Thai-Doc-Broker* THEN IF *request received from Employed-Migrant*

	THEN *make offerDocumentation(t) to match request for passport AND/OR work permit* END END

A.7.18 Verification

"A prerequisite to understanding a simulation is to make sure that there is no significant disparity between what we think the computer code is doing and what is actually doing." (46, 1.3)

We have completed verification steps to check the 'internal validity' of the MyTh MaP-IN ABM. Our verification process set out to answer these questions:

1) Do the lines of code (i.e., the computational model) map to the conceptual model as describe in the Sub-Model schematics and IF-THEN rules?
2) Are there any semantic or logical errors in the code?
3) Are there any artefacts (i.e., unintended or unnamed assumptions) that might be significantly influencing the model observations?

Verifying any ABM is challenging because the aim of the method is to study emergence, so it can be difficult to distinguish 'unexpected' outcomes resulting from the complexity of the model as opposed to unexpected outcomes due to an error or artefact in the model code (46, 47). This is particularly difficult when a simulation includes many heterogenous interactions and decisions, such as in the MyTh MaP-IN ABM. This work was guided by multiple sources for technical guidance (48–50), most notably the work of Galan and colleagues describing errors and artefacts in ABMs (46).

Sub-Model Verification Stages

The MyTh MaP-IN sub-models were each checked for errors and verified progressively in four stages (i.e., Sub-Model 1, Sub-Models 1-2, Sub-Models 1-3, and Sub-Models 1-4) for artefacts. It was not within the scope of this work to verify Sub-Models 2, 3 and 4 outcomes isolated from the preceding Sub-Models, although this is an area of potential future verification methods. Likewise, it was not within the scope of this work to use any formal methods of verification, such as model replication or exploring multiple updating techniques (51). These formal methods of replication offer new ways to interrogate models for any underlying artefacts causing the model's emergent properties, instead of the explicit mechanisms being modelled.

Other similar work has been attempted to reproduce an original model using a different modelling method to both verify and validate the original model (51, 52). These formal methods are outside the scope of this work, but are evaluation methods to consider applying in the future.

Sub-Model Verification Steps (at each 'stage')

The verification process for this ABM included the following three steps:

Step 1: Identify semantic errors - Are there any typos or naming mistakes?

Semantic errors: In a similar style to 'paired programming', the programmer and modeller have worked together to iteratively check the code for any typos or naming errors. The modeller used the Sub-Model documentation as a guide while reviewing the ABM code to ensure agents, variables, and rules had been named consistently and that the code was written in a similar narrative order as the Sub-Model schematics and tables to ensure easy cross-referencing between the documentation and the code.

Step 2: Identify logical errors - Does the computational model (i.e., lines of code) execute the essence of the outlined conceptual model (i.e., IF-THEN rules)?

Logical errors: Again, using the Sub-Model documentation as a guide, the modeller and programmer checked the code to identify any logical discrepancies between what the rules were instructing to happen and what the code was executing. Through this process, the modeller and programmer also added additional annotations to the code to explain the logic of the rules in a way that will help others with a range of technical backgrounds understand the code.

Step 3: Expected outcome alignment and artefact checking: Given the trends when rules are fired and the higher-level outcomes, are there any possible assumptions underlying the rules that are misaligned with the target phenomenon, as described in the conceptual model?

Expected outcome alignment and artefacts: The modeller and programmer independently review the data output files to review the range and

distribution of parameter values for any obvious abnormalities. The data output is also checked for how often rules were 'fired' and to what affect. This step also includes a higher-level check of aggregate outcome trends (i.e., how many migrants change state, how many migrants use certain pathways) to see if the general dynamics of the sub-model align with expectations of that sub-model. Reviewing the frequency and trends of rule firing and outcomes will help to identify any artefacts (i.e., assumptions in the model that the modeller or programmer may have thought were insignificant or did not know were there but are having significant impact on model outcomes). A full list of model assumptions can be found in Section A.7.19.

The two error checking steps were repeated for each sub-model and the expected outcome alignment and artefact checking were completed for Sub-Model 1, Sub-Models 1-2, Sub-Models 1-3, and Sub-Models 1-4, detailed in Appendix 8.

A.7.19 Sensitivity analysis

The MyTh MaP-IN has many parameters, and it was outside of the scope of this work to evaluate the sensitivity of the model outputs to every model parameter. Instead, the sensitivity analysis (SA) focused on evaluating the sensitivity of the model outputs to two key model attributes that might have a strong influence on the migration process (planning and execution) and be most relevant to intervention responses – migrant **preferences** and intermediary **links.** To test the sensitivity of the model to the interaction of these two model features, we have established three possible values for each feature and combined them in nine different ways (Table 19).

Table 19. Sensitivity analysis two-factor combinations

Sensitivity Analysis - Model elements				Model element - Combinations		
	Migrant preferences	Intermediary to Intermediary links		id	Migrant preferences	Intermediary to

Baseline	intermediary = 15% family =15% legal = 5% fees = 5% social = 15% work = 15% sector = 15% wage = 10% proximity = 5%	Facilitator-Recruiter = 25% MDB-Recruiter = 10% Employer-TDB = 50% Facilitator-Smuggler = 100% Facilitator-Employer = 25% Recruiter-Employer = 100% Smuggler-Employer = 10%
Value 1	**Migration Focus:** intermediary = 25% family =25% legal = 25% fees = 25% ELSE = 0%	**Fewer Links:** Facilitator-Recruiter = 0% MDB-Recruiter = 0% Employer-TDB = 25% Facilitator-Smuggler = 50% Facilitator-Employer = 25% Recruiter-Employer = 75% Smuggler-Employer = 0%
Value 2	**Destination Focus:** social = 20% work = 20% sector = 20% wage = 20% proximity = 20% ELSE = 0%	**More Links:** Facilitator-Recruiter = 50% MDB-Recruiter = 35% Employer-TDB = 75% Facilitator-Smuggler = 100% Facilitator-Employer = 75% Recruiter-Employer = 100% Smuggler-Employer = 35%

		Intermediary links
SA1	Baseline	Baseline
SA2	Baseline	Value 1
SA3	Baseline	Value 2
SA4	Value 1	Baseline
SA5	Value 1	Value 1
SA6	Value 1	Value 2
SA7	Value 2	Baseline
SA8	Value 2	Value 1
SA9	Value 2	Value 2

A.7.20 Validation

The MyTh MaP-IN model was validated at multiple levels (Table 20).

Table 20. Multi-level validation

Level of representation		Validated elements	Validation method
Micro-level	**Entities, properties, & rules**	• Preference • Initiation • Offers • Decisions • Plans	Inductive analysis that purposively compared the interview data from a set of randomly partitioned interviews (not included in the primary MMSNA study) to the ABM's micro-level model elements listed in this table.
	Processes	• Network emergence • Pathways	
System-level	**Patterns**	• Percentage of population that migrate • Percentage of regular vs. irregular pathways • Range of precarity scores across all migrants	Comparison of simulation event or outcome trends with similar quantitative empirical findings.

Micro-validation. For this first iteration, our model validation prioritised first validating the model rules. To do this, we partitioned a random 15% of the interviews for each of the three data collection site (n=15 interviews partitioned in total) and did not use these interviews in the primary MMSNA analysis presented in McAlpine and colleagues' corresponding paper which informed the model rules (17). After completing the model design and build, A. McAlpine compared the rules of the model and observed agent pathways to the migration narratives in these interviews to check if the model comprehensively included all these partitioned interview narratives, checking both that nothing of critical importance was missing from the model but also that nothing in the model contradicted the narratives in these interviews.

Additionally, the partitioned interview network data (i.e., structured egocentric network formations) were compared to the simulated emergent networks outputs in the model, again to check that the network structures presented in the interviews were represented in the simulated data as well.

System-validation. Also, as part of a first stage of validation of the model, we used the empirical data that informed the ABM, as well as the CHIME study and MLS survey to qualitatively validate the model outputs. We compared the total number of migrants that decided to migrate per simulated household to the population level findings of the CHIME and MLS survey. We assumed some of those figures were underestimates due to measurement challenges and missed households that migrated together and were not included in the surveys. We used the empirical data collected for this study to compare the baseline simulation's distribution of migrations across the different pathways and estimates for similar precarity indicators to check that the migration pathways and precarity outputs reflected the outcomes in our empirical data.

Due to Covid-19 restrictions, full validation of the model with expert stakeholder groups has not yet been feasible or within the scope of this work. In the future, we intend to complete additional model rule and initial full model validation with expert stakeholder groups, including groups of migrant workers.

References

1. Laatabi A, Marilleau N, Nguyen-Huu T, Hbid H, Ait Babram M. ODD+2D: An ODD based protocol for mapping data to empirical ABMs. JASSS. 2018; 21(2):9.

2. Grimm V, Berger U, DeAngelis DL, Polhill JG, Giske J, Railsback SF. The ODD protocol: A review and first update. Ecological Modelling. 2010; 221(23):2760–8.

3. Müller B, Bohn F, Dreßler G, Groeneveld J, Klassert C, Martin R, et al. Describing human decisions in agent-based models – ODD + D, an extension of the ODD protocol. Environmental Modelling & Software. 2013; 48:37–48.

4. McAlpine A, Demarest L, Zimmerman C, Kiss L. Visual network tools for mixed methods complex systems research: lessons from a study with migrants. Under Review, Journal of Mixed Methods Research. 2021.

5. McAlpine A, Kiss L, Zimmerman C, Chalabi Z. Agent-based modeling for migration and modern slavery research: a systematic review. Journal of Computational Social Science. 2020; 4:243–332.

6. Edmonds B, Le Page C, Bithell M, Chattoe-Brown E, Grimm V, Meyer R, et al. Different modelling purposes. JASSS. 2019; 22(3):6.

7. Jones K, Sha H. Mediated migration: A literature review of migration intermediaries. 2020.

8. Olynyk L. Meneshachin scoping study: A global synthesis and analysis of responsible recruitment initiatives targeting low-wage, migrant workers. Freedom Fund; 2020.

9. Hennessy E, Ornstein JT, Economos CD, Herzog JB, Lynskey V, Coffield E, et al. Designing an agent-based model for childhood obesity interventions: A sase Study of “ChildObesity180.” Prev Chronic Dis. 2016; 13(E04).

10. Epstein JM, Cummings DAT, Chakravarty S, Singha RM, Burke DS. Toward a Containment Strategy for Smallpox Bioterror: An Individual-Based Computational Approach. Brookings Institution Press; 2004.

11. Strategies for containing an emerging influenza pandemic in Southeast Asia | Nature [Internet]. [cited 2021 Apr 21]. Available from: https://www.nature.com/articles/nature04017.

12. Tracy M, Cerdá M, Keyes KM. Agent-based modeling in public health: Current applications and future directions. Annual Review of Public Health. 2018; 39(1):77–94.

13. Nianogo RA, Arah OA. Agent-based modeling of noncommunicable diseases: A systematic review. Am J Public Health. 2015; 105(3):e20–31.

14. Bersini H. UML for ABM. JASSS. 2011; 15(1):9.

15. Central Statistical Organization (CSO), United Nations Development Programme, World Bank. Myanmar Living Conditions Survey 2017: Socio-economic Report. Nay Pyi Taw and Yangon, Myanmar: Ministry of Planning, Finance and Industry; 2020.

16. Deshingkar P, Litchfield J, Ting W-C. Capitalising human mobility for poverty alleviation and inclusive development for Myanmar. Yangon, Myanmar: International Organization for Migration; 2017.

17. McAlpine A, Demarest L, Kiss L, Zimmerman C. Labour migration intermediaries, networks, and pathways in the Myanmar-Thailand corridor: a mixed methods social network analysis study. Under review, Social Network Journal. 2021.

18. Harkins B, Lindgren D, Suravoranon T. Risks and rewards: outcomes of labour migration in South-East Asia. Bangkok, Thailand: ILO Regional Office for Asia and the Pacific; 2017.

19. Massey DS, Arango J, Hugo G, Kouaouci A, Pellegrino A, Taylor JE. Theories of international migration: A review and appraisal. Population and Development Review. 1993; 19(3):431.

20. Brettell C, Hollifield JF, editors. Migration theory: talking across disciplines. 3. ed. New York, NY: Routledge; 2015.

21. Bakewell O. Relaunching migration systems. Migration Studies. 2014; 2(3):300–18.

22. Mabogunie A. Systems approach to a theory of rural-urban migration. Geographical Analysis. 1970; 2(1):1–18.

23. Haas H de, Castles S, Miller MJ. The Age of Migration: International population movements in the modern world. 6th ed. Red Globe Press; 2020.

24. Salt J, Stein J. Migration as a business: The case of trafficking. International Migration. 1997; 35(4):467–94.

25. Haug DS. Migration networks and migration decision-making. Journal of Ethnic and Migration Studies. 2008; 34(4):585–605.

26. Castles S. Understanding global migration: A social transformation perspective. Journal of Ethnic and Migration Studies. 2010; 36(10):1565–86.

27. Agunias DR. Guiding the invisible hand: Making migration intermediaries work for development. United Nations Development Programme; 2009.

28. Achilli L. The "Good" Smuggler: The Ethics and Morals of Human Smuggling among Syrians. The ANNALS of the American Academy of Political and Social Science. SAGE Publications Inc; 2018; 676(1):77–96.

29. Kley S. Explaining the stages of migration within a life-course framework. Eur Sociol Rev. Oxford Academic; 2011; 27(4):469–86.

30. Zimmerman C, Kiss L, Hossain M. Migration and health: A framework for 21st century policy-making. PLOS Medicine. Public Library of Science; 2011; 8(5):e1001034.

31. Haas H de. A theory of migration: the aspirations-capabilities framework. Comparative Migration Studies. 2021; 9(1):8.

32. O'Connell P. Migration Under Uncertainty: "Try Your Luck" or "Wait and See." Journal of Regional Science. 2002; 37:331–47.

33. Baláž V, Williams AM, Fifeková E. Migration decision making as complex choice: Eliciting decision weights under conditions of imperfect and complex information through experimental methods. Popul Space Place. 2016; 22(1):36–53.

34. Echeverría G. Towards a Systemic Theory of Irregular Migration: Explaining Ecuadorian Irregular Migration in Amsterdam and Madrid [Internet]. Cham: Springer International Publishing; 2020 [cited 2021

Mar 29]. Available from: http://link.springer.com/10.1007/978-3-030-40903-6.

35. Lewis H, Dwyer P, Hodkinson S, Waite L. Hyper-precarious lives: Migrants, work and forced labour in the Global North. Progress in Human Geography. 2015; 39(5):580–600.

36. Deshingkar P. The making and unmaking of precarious, ideal subjects – migration brokerage in the Global South. Journal of Ethnic and Migration Studies. Routledge; 2019; 45(14):2638–54.

37. Deshingkar P. Migration, brokerage, precarity and agency. Brighton, UK: University of Sussex; 2019.

38. Deshingkar P, Awumbila M, Kofi Teye J. Victims of trafficking and modern slavery or agents of change? Migrants, brokers, and the state in Ghana and Myanmar. Journal of the British Academy. 2019; 7 (s1):77–106.

39. McAlpine A, Demarest L. Myanmar-Thailand Migration Planning & Intermediary Networks Agent-Based Model. GitHub [Internet]. 2021. Available from: https://github.com/feature-creature/MyThMaP-IN.

40. McAlpine A, Demarest L, Chalabi Z. MyTh MaP-IN: Myanmar-Thailand Migration Planning & Intermediary Networks (Version 1.1.0) [Not yet peer-reviewed or public]. CoMSES Computational Model Library [Internet]. 2021. Available from: https://www.comses.net/codebases.

41. Stark O, Micevska M, Mycielski J. Relative poverty as a determinant of migration: Evidence from Poland. Economics Letters. 2009; 103(3):119–22.

42. Haan A de, Yaqub S. Migration and Poverty: Linkages, Knowledge Gaps and Policy Implications. Geneva, Switzerland: United Nations Research Institute for Social Development; 2009.

43. Stark O, Taylor JE. Migration Incentives, Migration Types: The Role of Relative Deprivation. The Economic Journal. 1991; 101(408):1163–78.

44. Thailand Bound: An Exploration of Labor Migration Infrastructures in Cambodia, Myanmar, and Lao PDR. MA, USA: Verite; 2019.

45. Harkins B. Base motives: The case for an increased focus on wage theft against migrant workers. Anti-Trafficking Review. 2020; (15):42–62.

46. Galan JM. Errors and artefacts in agent-based modelling. JASSS. 2009; 12(1):1.

47. Axelrod R. Advancing the Art of Simulation in the Social Sciences. Simulating Social Phenomena. Berlin, Heidelberg: Springer; 1997.

48. Gilbert GN, Troitzsch KG. Simulation for the social scientist. 2nd ed. Maidenhead, England ; New York, NY: Open University Press; 2005.

49. Wilensky U, Rand W. An introduction to agent-based modeling: modeling natural, social, and engineered complex systems with NetLogo. Cambridge, Massachusetts: The MIT Press; 2015.

50. Crooks A, Malleson N, Manley E, Heppenstall A. Agent-Based Modelling and Geographical Information Systems: A Practical Primer. First edition. Thousand Oaks, CA: SAGE Publications Ltd; 2018.

51. Kehoe J. Replication in agent based models using formal methods and multiple updating strategies [Doctor of Philosophy]. Dublin, Ireland: Dublin City University; 2017.

52. Chattoe-Brown E, Gilbert N, Robertson DA, Watts C. Reproduction as a Means of Evaluating Policy Models: A Case Study of a COVID-19 Simulation. medRxiv. Cold Spring Harbor Laboratory Press; 2021; 2021.01.29.21250743.