A Methodology to Develop Agent-Based Models for Policy Design in Socio-Technical Systems Based on Qualitative Inquiry

Nespeca, V.; Comes, M.; Brazier, F.M.

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A Methodology to Develop Agent-Based Models for Policy Design in Socio-Technical Systems Based on Qualitative Inquiry

Vittorio Nespeca, Tina Comes, and Frances Brazier

Abstract Agent-based models (ABM) for policy design need to be grounded in empirical data. While many ABMs rely on quantitative data such as surveys, much empirical research in the social sciences is based on qualitative research methods such as interviews or observations that are hard to translate into a set of quantitative rules, leading to a gap in the phenomena that ABM can explain. As such, there is a lack of a clear methodology to systematically develop ABMs for policy design on the basis of qualitative empirical research. In this paper, a two-stage methodology is proposed that takes an exploratory approach to the development of ABMs in socio-technical systems based on qualitative data. First, a conceptual framework centered on a particular policy design problem is developed based on empirical insights from one or more case studies. Second, the framework is used to guide the development of an ABM. This step is sensitive to the purpose of the model, which can be theoretical or empirical. The proposed methodology is illustrated by an application for disaster information management in Jakarta, resulting in an empirical descriptive ABM.

Keywords Qualitative research · Agent-based modelling · Exploratory research · Disaster information management

1 Introduction

Agent-based models (ABM) are powerful tools to support policy design in socio-technical systems by explaining the collective consequences of individual choices and behaviour. ABM can be used for a range of applications especially in policy design and analysis [10, 12]. However, designing ABM of socio-technical systems that reflect empirical evidence remains a challenge [25, 31].

Qualitative methods allow to account for the contextual richness of case studies. This richness is especially important in socio-technical systems, characterized by a dynamic complexity that normally hinders understanding cause-effect relations

V. Nespeca (✉) · T. Comes · F. Brazier
Delft University of Technology, Jaffalaan 5, 2628 Delft, BX, The Netherlands
e-mail: v.nespeca@tudelft.nl

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[31]. Qualitative data is typically in textual form, and is obtained from fieldwork, interviews, participant observations, or documents [31]. Translating this nuance-rich qualitative data into quantitative simulation code is not a straightforward task [19]. Bridging such a gap between qualitative data and ABM requires preserving the contextual richness of the data collected, avoiding distortions, providing transparency in the chain of evidence from data to model, and ensuring replicability [8, 31].

Several methodologies have been proposed to bridge this gap by (a) using previously developed frameworks and/or by (b) "constraining" the knowledge elicitation process through clear steps [8]. For instance, [17] shows the potential of using conceptual frameworks developed for institutional (re)design to support the design, implementation and analysis of ABM in socio-technical systems. Further, [16] provides an approach for structuring and interpreting qualitative data from ethnographic work on the basis of a previously developed framework (or metamodel). Conversely, [3] suggest a mixed-methods research methodology that puts emphasis on the steps adopted to extract and validate agent rules via a participatory and ethnographic process. The authors rely on an exploratory phase to design a context-specific game that captures the world views and decisions of the participants. The game is then used to extract agent rules.

Despite these advances in the field, a methodology is missing that allows to (i) explicitly design a conceptual framework centered on a particular policy design problem and (ii) use such a framework in the development, implementation and analysis of ABMs thus contributing to the policy design process. In this paper, a methodology is presented addressing this gap. The methodology focuses on the development of ABMs for policy design in socio-technical systems based on qualitative methods and more specifically exploratory case-study research. It accounts for the contextual richness of a case study and is sensitive to the modelling purpose (theoretical or empirical).

2 Proposed Methodology

The methodology introduced in this article involves two interlinked phases: framework and model development, see Fig. 1. In phase one, a framework is developed based on existing knowledge and one or more case studies. In phase two, a model is developed based on the framework, along with insights from literature and empirical data from the case studies.

2.1 Phase 1: Framework Development

In this phase, an exploratory approach is used to design a conceptual framework. The framework has to be designed from the perspective of *a carefully-chosen unit of analysis*. This unit refers to the micro-level entity that is going to the center of

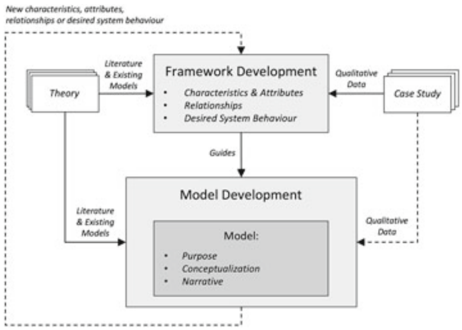

Fig. 1 Methodology for developing ABMs grounded in qualitative research. The dashed line symbolizes optional activities

the ABM. Given the generative nature of ABM [11], it is crucial that the framework takes the perspective of the intended model's most elementary unit. Examples of unit of analysis are a person, a household, or an organization.

The framework provides the means to analyze (a) the system's configuration and change, and (b) the system's behaviour. To allow such analyses the framework includes respectively the (a) system's characteristics and their attributes, together with the relationships among such characteristics, and (b) the desired system's behaviour expressed in terms of specific criteria for assessment. The analysis of system's configuration is carried out by studying the characteristics and attributes, resulting in the units of analysis, objects they interact with, and other relevant entities that compose the considered system (including the environment) and their attributes. The analysis of system's change is carried out by studying the relationships among characteristics and it provides the activities and interactions across different units of analysis and the objects. The analysis of system's behaviour consists in using criteria for assessment to analyze the extent to which the current system achievers the desired system's behaviour. Designing policies within the given system means altering the system's configuration to achieve the desired behaviour.

Framework Development Steps: Given that socio-technical systems are inherently complex, Brazier et al.'s approach for the design of complex systems is adopted for the framework development [5]. The framework is developed according in four steps (adapted from [23]): exploratory literature review, requirements design, case study, framework design.

1. Exploratory literature review: The researchers explore the literature and existing models (including ABMs) related to the type of system in question in order to identify (a) the type of problem to be addressed via policy design, (b) the unit of analysis for the given type of problem, and (c) a list of relevant system's features from the perspective of the unit of analysis.

2. Requirements design: Brazier et al.'s approach entails the design of the system's mission and of the associated functional, behavioural and structural requirements [5]. The mission of the system is its intended purpose. The functional requirements are the functions that the system has to fulfill in order to achieve the mission. Behavioural requirements define the desired system behaviour associated with the fulfilment of the functional requirements, and the assessment criteria that can be used for measuring the extent to which the desired systems behaviour is achieved. Structural requirements are the components of the system, including those put in place in order to fulfill the behavioural requirements.

Based on the problem identified from literature, the researchers set a system's mission and design the preliminary functional and behavioural requirements (or desired behaviour), resulting in a preliminary list of criteria for assessment. The researchers also design the structural requirements based on the list of relevant system's features from the perspective of the unit of analysis, resulting in a preliminary list of system's characteristics, attributes and relationships.

3. Case study: In this step, the preliminary list of characteristics, attributes, relationships and criteria for assessment are verified and expanded based on a case study. First, the field study is designed. This includes the selection of a case study (e.g. [15]), data collection techniques (interviews and focus groups, participant observations and archival data), and sampling strategies (e.g. [22]) all of which are summarized in a data collection plan. The collected data is then analyzed through *coding*. The way such analysis is carried out depends on the type of data collection techniques chosen. However, in all cases the analysis begins with the preliminary characteristics, attributes, relationships and criteria for assessment.

In the case of interviews, focus groups, and participant observations the collected data is analyzed with a hybrid deductive and inductive coding approach [13]. Initially, a coding schema is defined based on the preliminary characteristics, attributes, relationships and criteria for assessment from the previous step. More specifically, codes of the first level are defined as (a) the preliminary system characteristics and (b) the system's behaviour. The codes of the second level for (a) are defined as the attributes and relationships, whereas the codes of the second level for (b) are defined as the criteria for assessment. During the coding process, not only instances of the pre-defined codes are found, but also an open (inductive) coding approach is adopted to find new system characteristics, attributes, relationships, desired system's behaviour and criteria for assessment.

In the case of archival data or documents, the summative content analysis approach is adopted [18]. This approach is divided in two levels, namely manifest and latent. The manifest level entails finding in the archival data occurrences of the codes associated with the preliminary characteristics, attributes, relationships and criteria for assessment. At this stage, new characteristics, attributes, relationships and criteria for assessment may also be found through open coding. Next, the latent level focuses on analyzing the context in which the code occurrences were found to study and revise their meaning. In the process, further instances of the codes may be found, and also new codes may be introduced. Typically, an iterative process is required between the manifest and latent levels to determine how well the meaning extrapolated from given contexts fits that associated with the codes and solve potential conflicts.

4. Framework design: The design process of the framework is based on the system characteristics, attributes, relationships, and criteria for assessment from the previous step. Each system characteristic is considered as an independent framework component, with its own attributes and relationships. When the relationships found between the system's characteristics are vertical, such as those of the type "is a part of", "can have one or more" or "contains", then the corresponding characteristics are organized hierarchically, i.e. as a box in a box. Whereas, when the relationships among given characteristics are horizontal, such as those of the type "interacts with", "causes", "perform" and "affect" then these characteristics are organized as a box besides a box and linked with an arrow labeled with the corresponding relationship. The behavioural requirements are used to capture the systems behaviour through the criteria for assessment.

2.2 Phase 2: Model Development

Previous work suggests that it is good practice to set a clear modelling purpose since the early stages of model design as the way a model is developed, justified and also scrutinized by the scientific community depends on its purpose [4, 10]. Therefore, the model development process suggested in this article takes different forms depending on the purpose of the model. More specifically, a distinction is drawn between models with an empirical or theoretical purpose[1,2] affecting the way the framework is used in the development process.

Model Development Steps: Several methodologies have been proposed in the literature for the development of ABMs. In this article, the approach proposed in [24] is extended to include the use of the framework from the previous phase to guide the model development process. The resulting approach involves the following iterative model development steps: Problem Formulation, System Identification and Composition, Model Concept Formalization, Model Narrative Development, Software Implementation, and Model Evaluation. In the following sections, each step is described stressing how the framework is used to guide model development for empirical and theoretical models.

1. Problem Formulation: The problem formulation entails decisions about (a) the modelling purpose and (b) the system behaviour of interest and the associated criteria for assessment.[3]

In the case of empirical models, the choice of a modelling purpose and system behaviour of interest is guided by the results of the framework application to the case study and resulting analysis of system configuration and change, and analysis of system's behaviour (see Sect. 2.1). Empirical models can be employed to provide

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[1] *Empirical models* have a direct relationships with a specific case study. Descriptions, explanations and predictions are examples of empirical modelling purposes. *Theoretical models* do not have a direct relationship with any case study. Illustrations and theoretical expositions are examples of theoretical modelling purposes [10].

[2] With this distinction, the authors do not imply that theoretical models cannot be used in practical settings. However, theoretical model can be applied in practice only if their micro assumptions and macro implications have been empirically tested [14].

[3] New criteria or more detailed criteria may be introduced at this stage compared to those presented in the framework.

a description of the current configuration and dynamics of a given system on the basis of the analysis of system configuration and change. This can be a first step for the development of future models aimed at supporting policy design for the given case ([30] is an example of a description). In other cases, the analysis of system behaviour uncovers that the system performs poorly or particularly well in terms of specific criteria for assessment. As such, the researcher may decide to focus on providing explanations in terms of the mechanisms that led to such system behaviour (see for instance [1]). Finally, empirical models may be chosen with the purpose of exploring the implications of future policy interventions e.g. aimed at addressing the poor performance uncovered by the analysis of system behaviour [9].

In other cases, the researchers may wish to develop a theoretical model that abstracts from the context of the given case study to capture a range of systems [4]. Such models can for instance have the purpose of illustrating or exploring relationships between given system characteristics or policies and the resulting system behaviour, and producing hypotheses to be tested empirically [2]. In these cases, the researcher may choose a modelling purpose within the broader scope of the mission of the framework. The relevant system's behaviour depends on the modelling purpose chosen. The framework, and more specifically its assessment criteria, can support the definition of relevant categories of systems behaviour. The researcher in this case has to decide which of such criteria are relevant for the specific modelling purpose.

2. System Identification and Decomposition: System identification involves defining the boundaries of the considered system. System decomposition consists in listing the instances of the units of analysis, their actions and interactions, objects they interact with and the environment they are in.

In the case of empirical models, the boundaries of the system can be those of the case study to which the framework was applied. However, the researcher may decide to narrow the considered system down to a specific area. The system decomposition is derived from the analysis of configuration and change obtained through the framework application (see framework application in Sect. 2.1).

With regards to theoretical models, the system identification and decomposition is meant to capture an abstract system, rather than a specific case study. The framework can support system decomposition by providing an inventory of system characteristics, attributes and relationships of which the researcher may decide to introduce instances in the considered abstract system. Previously existing models and ontologies can be used for the same purpose.

3. Concept Formalization: In this step, the system identification and decomposition is formalized in a format that can be translated into software. All the entities that will become agents are organized hierarchically from more general classes to those representing the agents actually considered in the model. A concept formalization can be implemented directly as software data structure or as an ontology (which is then translated into a software data structure).

4. Developing a Model Narrative: At this stage, all activities the agents carry out including their interactions with other agents and with the environment are organized into a narrative. One way of proceeding is to develop a narrative starting from general classes that capture similar activities for many agents and then extend the general narrative to include the details for each type of agent. The detailed narrative is then formalized as pseudo code.

5. Software Implementation: In this step, the model conceptualization and narrative are implemented in an adequate modelling environment such as NetLogo, Repast Symphony or GAMA.

6. Model Evaluation: Model evaluation is an activity that occurs throughout the development of a model. Evaluation can take different forms including verification and validation. Verification focuses on assessing whether the model corresponds to the intentions of the modeller. Validation is concerned with evaluating if the model corresponds to the reality it aims to capture [24]. Depending on the modelling purpose, validation and verification assume a different relative importance [10]. Theoretical models are not directly connected to a particular case study. As such, there is a stronger focus on verification rather than validation. Conversely, empirical models aim to capture a given case study, and therefore typically require a stronger emphasis on validation. Descriptive empirical models do not aim to reproduce the system behaviour but only to combine knowledge gathered through the case study with previously available knowledge and models. Therefore, such models require solely a validation in terms of their model conceptualization and narrative. Other empirical models that aim at reproducing the system behaviour need to be validated not only in terms of the model conceptualization and narrative, but also with regards to their ability to reproduce system behaviour. In such cases, the results of the analysis of system behaviour from the framework application (see Sect. 2.1) can be used here as the output to be matched by the model.

2.3 Iterative Model and Framework Development

Due to the exploratory nature of the proposed methodology, the model development phase is likely to produce new knowledge regarding relevant systems characteristics, attributes, relationships or system behaviour that are not included in the framework designed in phase one. As such, this knowledge can be incorporated back in the framework for future use.

3 Methodology Application: A Case Study on Disaster Information Management in Jakarta

In this section, a case study of disaster Information Management (IM) in Jakarta, Indonesia is used to illustrate the use of the methodology. The following sections provide information on the case study, show how a framework was designed based on the case study (phase 1), and how this framework was used to develop an empirical model (phase 2).

3.1 Case Study

When disasters such as floods and storms hit, both formal and informal organizations and communities need to adapt to the ever-changing and often unexpected conditions [7]. Their ability to self-organize, coordinate and respond to the situation strongly relies on the timeliness and quality of the information available [23, 29]. At the same time, with the dynamically evolving situation, the roles and information needs of the actors continually change [20, 27]. Designing for coordination and self-organization in disasters thus mandates the design of strong IM policies to ensure that information of good quality reaches the actors who need it when they need it. Such policies need to take into account the socio-technical nature of disaster response systems, as the way information is collectively managed often depends on the interplay between human behaviour and the use of technology (e.g. mobiles and social media) [26]. The authors in this case were specifically interested in the design of bottom-up IM policies.

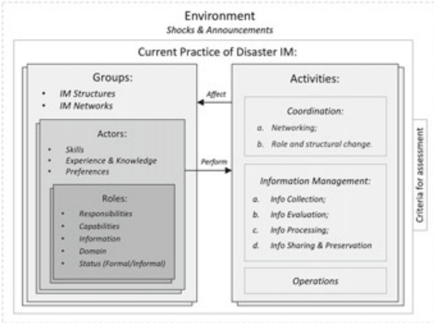
Jakarta represents a critical case of bottom-up disaster IM as (a) it is affected by very frequent flooding and (b) because of such floods, many bottom-up IM initiatives have been initiated in the city in the recent years, often aided by social media and messaging apps [28]. Another reason for choosing Jakarta was that at the time of data collection (in 2018) many international organizations were in the city due to the humanitarian response to the Sulawesi Earthquake. This provided the opportunity to interview their representatives in person. The data collection plan was designed on the basis of an exploratory interview carried out before visiting the field. However, further participants were found through snowballing during the data collection. In total, 9 semi-structured interviews and 3 focus groups were carried out in the field. Altogether, 25 participants were involved in the data collection, ranging from the information managers of national and international governmental and non-governmental organizations, to the members of highly affected communities in the city.[4] More information on the case study, including data collection and analysis can be found in [23].

3.2 Phase 1: Framework Development

Firstly, a review of the relevant literature and existing ABMs on disaster IM was carried out. This lead to the identification of the policy design problem as the design of IM policies that can support both coordination and self-organization in disaster

[4] Two of the most affected communities in the city were considered: Marunda and Kampung Melayu.

Fig. 2 Framework, adapted from [23]



response by satisfying the continually shifting information needs of individual actors. As such, the unit of analysis chosen for the framework is that of an individual person (or actor). A list of relevant system's features was also derived from the current literature and existing ABMs.[5]

Secondly, based on these results, the system's mission was identified as: "*to provide relevant, reliable and verifiable information to the actors who need it, when they need it in an accessible manner*". Together with the mission, also the functional, behavioural and structural requirements were designed. Thirdly, these requirements were validated and expanded with a case study, leading to the refinement of some the behavioural requirements (relevance and timeliness).

Next, based on the requirements a framework was designed with the twofold purpose of (a) providing the means to analyze the current practice of disaster IM in a case study, including the way such practice changes through self-organized bottom-up processes (analysis of system's configuration and change), and (b) analyzing the extent to which the current practice supports coordination and self-organization (analysis of system's behaviour). The criteria for the assessment of the extent to which the system's mission and desired system behaviour are achieved are information relevance, timeliness, accessibility, reliability, verifiability and load. Figure 2 shows the resulting framework. The full details of framework development process are in [23].

3.3 *Phase 2: Model Development*

In this phase, the framework was used to develop an empirical model. The following sections explain the model development process in detail.

1. Problem Formulation: A model with a descriptive purpose was chosen to capture some of the main characteristics and dynamics of the current practice of disaster IM in Marunda. This model is the first step in building a simulation environment that

[5] For instance, the conceptualization of the environment in a crisis as a series of cascading shocks producing information needs was introduced as in [21].

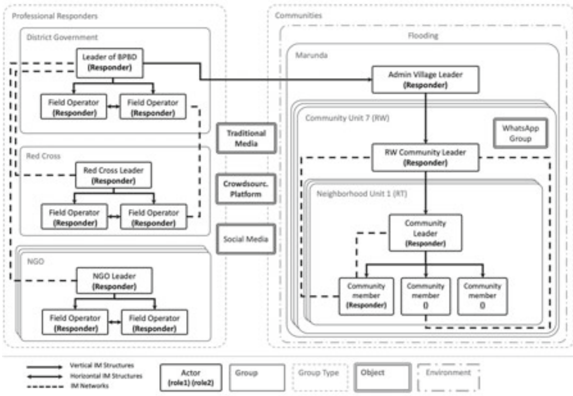


Fig. 3 System Identification and Decomposition: configuration of the current practice of Disaster IM in Marunda, Jakarta. Adapted from [23]

will be used to explain the current behaviour of the system given its current practice (possibly informing policy design) and to evaluate the impact of different disaster IM policies on the system behaviour. In terms of relevant system's behaviour, information relevance and timeliness were chosen as the assessment criteria to be captured in the model output based on the results of the analysis of system's behaviour [23].

2. System Identification and Decomposition : The purpose of the model is to capture the dynamics within the community, and its interactions with other relevant actors. As such, the system boundary includes the Marunda community, as well as the governmental and non-governmental organizations and groups that (may) exchange with the community.

The system decomposition was carried out by applying the framework designed in the previous phase, and more specifically by carrying out the analysis of system's configuration and change (cf. Sect. 2.1).This meant identifying the key actors and roles they assume, groups they belong to, structures and networks through which they share information, activities they carry out, and the environmental factors that play a role in IM. During the data analysis, one system characteristics was found that had not been included in the framework, namely that of objects. Objects are any non-human entities that can support IM and coordination activities of the actors (cf. Fig. 2). Figure 3 shows the resulting system identification and decomposition for the Marunda community.

3. Concept Formalization: Based on the system decomposition, a list of the relevant entities was developed, including their properties, states, and activities. When such entities had common states, properties or activities and could therefore be seen as instances of a more abstract entity, a new entity was introduced. This led to the definition of abstract entities such as "Actors" or "Objects". Figure 4 shows the resulting conceptualization including both the general entities and their instances for the specific case of Marunda.

4. Developing a Model Narrative: Starting from the general conceptualisation from the previous step, a narrative was developed by organizing the activities carried out by the general "Actor" into a sequence of actions (see Fig. 4), resulting in the

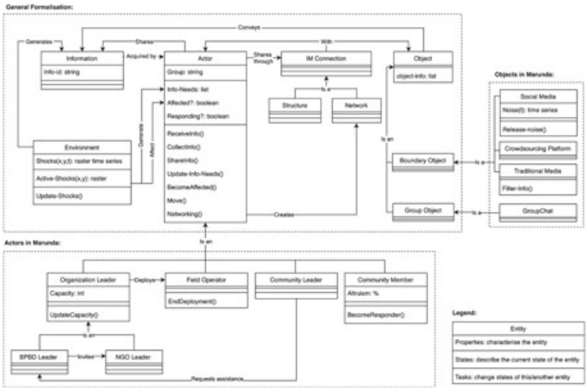


Fig. 4 Concept Formalization: UML description of entities, their properties, states and activities

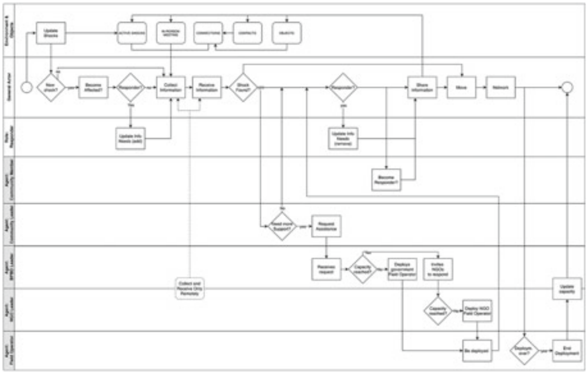


Fig. 5 Developing a Model Narrative: narrative of disaster IM for the general actor (first three rows) and its instances (following rows)

first three rows of the flow chart shown in Fig. 5. Next, specific sub-narratives were developed for each of the instances of "Actor" given their specific activities and interactions. Such sub-narratives were then introduced in the general actor's one, resulting in the "swim lanes" diagram shown in Fig. 5. The same process was carried out for "Object".[6]

5. Software Implementation: Implemented in NetLogo 6.1.1.

6. Model Evaluation: The empirical model was verified thoroughly through single agent, interaction and multi-agent testing as suggested in [24]. A validation was not performed at this stage and will be carried out as a future step. Given its descriptive purpose, the model developed is not intended to reproduce precisely the system behaviour observed in reality. The goal is rather to formalize and combine the knowledge gathered through an exploratory study for the Marunda community together with previously available theory and models on crisis IM. As such, the validation in this case will not focus on assessing whether the model reproduces the behaviour observed at the macro level in the Marunda community via the analysis of system's behaviour (see [23]). It aims at ensuring that the model conceptualization

[6] Omitted in this article for brevity.

and narrative match the way information is managed at the micro level in the case study. This will be achieved by discussing the model conceptualization and narrative with the members of the Marunda community and other organizations captured in the model.

3.4 Iterative Framework Development

In the model development phase a new system characteristic was found, namely that of "Objects", connecting groups and enabling certain activities. Objects and their relationships with the other system's characteristics were integrated in the framework. The resulting framework is shown in Fig. 6 and it can be used in substitution of the one developed in [23] (Fig. 2).

4 Discussion

This article fills a gap in the literature by proposing a methodology for the development of ABMs for policy design in socio-technical systems. It allows to capture the contextual richness of a case study based on qualitative data and exploratory research and translate it into an ABM. The methodology builds on [24] to include the design and use of frameworks in the development of ABMs with different modelling purposes [10] and it is structured in two phases. In the first phase, a conceptual framework centred on a specific policy problem is designed based on a case study. Such a framework includes the system's mission, its relevant characteristics and relationships, and the criteria for assessment (or indicators of system behaviour) that can capture the extent to which the mission is achieved by a given policy. In the second phase, the framework is used to guide the development of an ABM. The way the framework is used depends on whether the model is directly related to a case

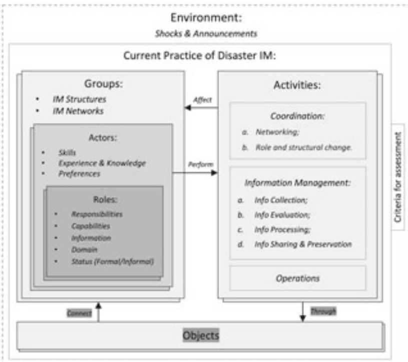


Fig. 6 Updated framework with the new systems characteristics and relationships (highlighted in the figure)

study (empirical) or not (theoretical). In the case of empirical models the framework is applied to a case study to analyze the system configuration and change, and the system's behaviour. Based on these analyses, a context specific model is developed. In the case of theoretical models, the framework provides an inventory of (a) systems characteristics, attributes and relationships of which the researchers may decide to introduce instances in the considered abstract system and (b) a list of criteria for assessment as indicators of the system's behaviour that the researchers may wish to study.

This methodology was illustrated through a case study of disaster IM in Jakarta. A conceptual framework centered on the design of disaster IM policies was designed based on the available literature and case study interviews. The framework enabled the analysis of (a) system's configuration and change, and (b) system's behaviour. These analyses were instrumental in the development of a descriptive ABM capturing the current practice of disaster IM in the Marunda community. During model development new systems characteristics and relationships were found. These were integrated in the framework for future use.

The case study showed how the methodology allows to collect context-rich qualitative data and translate it into an ABM through a systematic and transparent process. The developed model has a descriptive purpose and as such it is only meant to capture and formalize the knowledge gathered on the current practice of disaster IM in the case study. While such a model does not aim to reproduce precisely the behaviour of the considered system, it paves the way for the development of further models which purpose could be (a) investigating explanations for the current behaviour of the system (possibly providing suggestions for policy design) and (b) exploring the impact of IM policies [10].

A key advantage of this methodology is that it centers the process of framework and ABM development on a particular policy problem. Specifically, the framework provides a common mission and criteria for the assessment of policy "performance", so that different socio-technical simulation studies focusing on the same policy design problem can be compared and built upon incrementally. Further, the process of designing policies supported by ABM may involve the development and use of a series of models with different purposes [10]. For instance, in this study an empirical ABM with a descriptive purpose is developed, based on which other empirical models e.g. with explanatory or exploratory purposes could be developed to support policy design. Theoretical models may also be needed e.g. with the purpose of illustrating the implications of a given policy designs in an abstract system prior to testing them empirically. As such, another advantage of the proposed methodology is its versatility in the development of ABMs for policy design with different (theoretical or empirical) purposes.

Despite these advantages, the methodology presents limitations providing ground for further research. Specifically, while the framework enables the analysis of a system and its decomposition, it is not meant to provide the level of detail required to capture the agents' internal processes. As such, the design of internal processes rests upon the model designers. While the authors believe that ABM design requires the skill and experience of the model developer, at least one direction to bring further structure and rigour to the development process is envisioned. Generic models such as the Generic Agent Model and its applications [6] can guide the design of the agents' internal processes as they provide an abstract and formalized understanding of the tasks that (can) occur within the agent. Such generic models could be integrated into the methodology to (a) guide the translation of the system decomposition into a model conceptualization and narrative and (b) aid the implementation into code.

5 Conclusions

Agent-based models for policy support in socio-technical systems need to be empirically grounded. Qualitative research methodologies allow to gather empirical evidence capturing the contextual richness of a case study. But, translating evidence of such into an ABM for policy design requires a systematic and transparent approach. This article introduced a methodology addressing this gap in two phases. Firstly, a conceptual framework is designed tailored to a specific policy design problem. Secondly, an ABM for policy design is developed through the framework. The use of the methodology was shown with a case study of disaster information management in Jakarta, Indonesia. As a result, a descriptive model of the current practice of disaster information management in the case study was developed. This is a first step in the development of further models that can support the design of information management policies in the case study. The proposed methodology has the advantage of centering ABM development on a common framework thus allowing for comparability and incremental design across different studies focusing on the same policy problem. Further, the methodology is versatile as it enables the development of models with different theoretical and empirical purposes to support the policy design process. Future research will focus on integrating the use of Generic Models in the methodology to improve its rigour by guiding the translation of a system decomposition into a model conceptualization and narrative.

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