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EXPLORATION OF PURPOSE FOR MULTI-METHOD SIMULATION IN THE CONTEXT OF SOCIAL PHENOMENA REPRESENTATION

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ABSTRACT

Difficulty of social phenomena representation can be related to limitations of used modeling techniques. More flexibility and creativity to represent social phenomena (an adequate mix of model scope, resolution, and fidelity) is desirable. The representation of social phenomena with a combination of different methods seems intuitively appealing, but the usefulness of this approach is questionable. Current view on the justification of multi-method has limitations in social science context, because it lacks a human dimension. This paper explores the literature that pertains to mixing methods, and displays current reasoning behind the use of the multi-method approach. The perspective on mixing methods from empirical social science projected onto M&S domain exposes high-level purposes related to representation of social phenomena with mixed method approaches. Based on the reviewed literature and qualitative analysis, the general view of ingredients for inferring purposefulness of the multi-method approach in the context of social phenomena representation is proposed.

1 INTRODUCTION

A multi-method M&S approach pertains to a combination of at least two M&S methods that combined allow for a unique system or phenomena representation and execution. At a more abstract mental dimension, the multi-method M&S approach could be perceived as a way of diverse representation through different mental models that direct to use of different M&S methods.

The multi-method M&S approach has already found its way to represent technical phenomena, for instance: in manufacturing (Rabelo et al. 2003); healthcare (Brailsford, Desai, and Viana 2010; Chahal and Eldabi 2008); and supply chain (Lee et al. 2002). In these papers, methods can often complement each other. Technical phenomena that are considered in these studies usually require only two levels of analysis; a macro level model represented using SD, and a meso level model using DES. Social phenomena are usually very complex and can include many metrics at more than two levels. Representation of social phenomena with a combination of different methods seems intuitively appealing, but this approach has not been given sufficient attention. In order to be more representative, social phenomena may require representation of intelligent entities and operate at many, not always well-bounded, levels of analysis. This intuitively seems more complex than representation of technical phenomena, which usually does not require representation of proactive behavior. Social phenomena representation must often preserve phenomena complexity in order to allow for exploration. Recently, communities that were usually focused on representation of technical phenomena also started investigation of social concepts to enhance their perspectives (Behdani 2012, Brailsford et al. 2011, Hoad and Watts 2012). Unfortunately, the usefulness of multi-method M&S to represent social phenomena is not well understood and clear. Answering even a seemingly basic question as to why to use multi-method M&S versus single method M&S approach to represent social phenomena is not straightforward.

Different M&S methods can contribute their advantages, forms of expressiveness, and different perspectives on capturing complexity of social phenomena. For instance, System Dynamics seems more suitable for capturing dynamic complexity (Sterman 2000), ABM is more suitable in representing complexity arising from individual behavior and interactions (Macal and North 2005) , and DES can well capture "black box" process complexity (Law 2007). Bayesian Based Methods (BBM) offer a unique probabilistic view, which can be used to represent decision-making processes and beliefs of agents (Hoad and Watts 2012, Lieberman 2012, Lee and Son 2008). Fuzzy Based Methods (FBM) allow for capturing vagueness of phenomena systematically (Verkuilen and Smithson 2006) and can be useful in social simulations (Hassan, Garmendia, and Pavón 2007). Triangulation of these methods is often valuable, but an even more challenging and possibly beneficial approach involves a combination of methods within a single model. Despite high appeal for mixing M&S methods to represent social phenomena, it is problematic that reasons and justifications for application of the multi-method M&S approach in this context have not yet been thoroughly investigated.

Because a multi-method simulation model seems intuitively more difficult to develop and validate, the tradeoffs should be systematically deliberated. Currently, attitudes for justification of the multi-method M&S approach were focused on aspects of methods considered, study problems, and system at consideration as seen through more technical lenses (Chahal 2010, Lorenz and Jost 2006). Chahal (2010) proposed the reasoning for use of multi-method M&S in the context of less complex technical phenomena representation as applied to the healthcare setting. Unfortunately, this technical view on justification of multi-method is limited to guide use of multi-method in social science context because it lacks the human dimension (methodological context and within the model itself). Glazner (2009) noticed that the decision as to which method to use in each different part of the system was a combination of the modeler preference and expected modeling effort, and two out of three views could be modeled using either of three methods considered. The only part that was directly leaning toward use of ABM was the "organizational unit", because of its individual behavior, which could not be represented using either SD or DES methods. This can indicate that in some cases, there is a gray area for choosing a method, but in other situations, there is a clear choice due to the requirements of the modeling effort. Human vagueness present in the reasoning behind the decisions to employ multi-method M&S should be explored because it is problematic even when representing more simplified technical phenomena, but especially with the goal to model social phenomena. Social phenomena representation needs methods and tools that allow for more creativity and flexibility which multi-method view seems to offer. On the other hand, showing and proving this is not an easy endeavor.

In this paper, exploration of justification for using multi-methods M&S approach in representing social phenomena is pursued. The following section provides an overview of purposes for the multi-method approach from relevant literature. Section 3 provides a review of the social science perspective on mixing methods according to Greene (2007), and projects it onto the M&S domain. Section 4 explores the findings from previous segments and proposes dimensions and guidelines for decision and justification of the multi-method approach in representation of social phenomena. Finally, Section 5 concludes the paper.

2 PURPOSES FOR MULTI-METHOD FROM RELEVANT LITERATURE

The review process is directed at finding the literature relevant to the multi-method M&S approach, including also so-called hybrid models, which are usually combinations of continuous and discrete methods and considered a form of multi-method (Chahal 2010, p. 9). This section of the literature review was divided into answering the following questions:

- What are the justifications or criteria for using multi-method M&S?

- Is current knowledge that justifies selection of the multi-method approach in building a simulation model that consists of social phenomena satisfactory?

2.1 What Are the Justifications for Using Multi-Method M&S?

Complementarity of methods. Eldabi, Paul, and Young (2006) have gathered information on M&S direction in the healthcare context in the form of synthesis of the trends identified by experts in the field. The reasons for combinations of methods and the need of hybrid methodologies given by respondents referred to "move[ing] away from perception that one method fits all" (p. 265), a need for a holistic systems view in representing large, complex, interconnected systems, and a need to include human elements. The *complementarity* of methods presumably mitigates assumptions prescribed within methods, allowing for shaping methodologies that are more flexible. Brailsford, Churilov, and Liew (2003) have demonstrated the *complementarity* of SD and DES. Morecroft and Robinson (2005) noticed that DES effectively captures detail complexity by tracking and analyzing of individual entities, but does not handle dynamic complexity easily because implementation of feedback loops is less intuitive and more difficult to build. The opposite is also true for SD. Kott and Corpac (2007) noticed that no one modeling method is truly relevant to the entire Diplomatic, Information, Military, and Economic (DIME) and Political, Military, Economic, Social, Infrastructure, and Information (PMESII) dimensions.

Coupling between methods. Both, Fahrland (1970) and Helal (2008) have considered use of a multi-method approach in cases where representation of system elements not only required different methods, but additionally a strong interaction between these methods. Subsequently, Chahal (2010) developed a framework in which the need for multi-method approach is reliant on strong interaction between methods.

Multilateral problems. Djanatliev et al. (2012) believe that a combination of methods could profit in assembling complex, large-scale simulation architectures, and that taking advantage of different modeling methods could help them in answering multiple questions about economic prognoses and impacts of different factors on patient's health. Currently, multi-method simulations are employed more often because problems of a more complex nature are being targeted (Swinerd and McNaught 2012).

Modeler preference and skills. It is clear that modeler preference plays a role in the use of a multi-method approach. Viana et al. (2012) explained that each subsystem was implemented using the best method, with the "best" meaning the method that most closely aligned with the mental models of designers. Glazner (2009) noticed that the decision on which method to use was a combination of the modeler preference and expected modeling effort most likely related to proficiency in using a modeling method. A modeler needs to make a decision about which method, or combination of methods, is the best or satisfactory choice for a given purpose. On the one hand, a modeler's expertise is often the determining factor for a method choice (Brailsford and Hilton 2001). However, if the modeler is unfamiliar with some crucial method in a given context, there is a danger of using a suboptimal method by adjusting problem to some known by the modeler methods. According to both Chahal (2010) and Lorenz and Jost (2006), the opposite, choosing tool to fit to the problem is the right approach. Lorenz and Jost (2006) informed that modelers could overlook modeling methods when deciding which ones suit the purpose because they are not very familiar with them or have biased preferences. This can lead to inability to compare alternative approaches and to choose methods based on sufficient judgment. It is possible that some social scientists are not acquainted with more than one simulation method, so they might not explore the potential for more flexibility and creativity in explaining or exploring social phenomena by integration of multiple simulation methods.

Stakeholder acceptability. Viana et al. (2012) point out that by using different methods suited better for different tasks, "the stakeholders have gained greater buy-in and understanding, where the stakeholders included both the problem owners (health care and social care professionals) and those members of the project team who are unfamiliar with the techniques" (p. 3). Similarly, a mixture of hard and soft OR methods allowed for better understanding, acceptance, and willingness to implement results by stakeholders (Sachdeva, Williams, and Quigley 2006).

Data availability. Lättilä, Hilletofth, and Lin (2010) suggested that data availability could also be a factor for choosing a multi-method approach. Because data availability often depends on phenomena studied, and because different data could align better with different methods, a multi-method approach could allow alignment with available data from different parts of the system that range from detailed individual agents' behavior to a global view.

Validity. Parunak, Savit, and Riolo (1998) pointed out that validation at multiple levels of analysis might be more difficult, but could deliver a more accurate model. Following this idea further, if a multi-method approach can facilitate modeling at multiple levels of analysis, it is possible that it leads to models that are more accurate as well. Crespo and Ruiz (2012) combined DES and ABM with a goal of obtaining estimation that is more accurate and a more realistic model of the Capability Maturity Model Integration (CMMI) process. Similarly, Siebers claimed that a combination of DES with ABS had a positive impact on model accuracy and allowed for "proactive behavior in service system models" (Hoad and Watts 2012, p. 68).

Unique representation. The need for more unique modeling approaches to represent proactive behavior was the reason for extending the Commander's Model Integration and Simulation Toolkit (CMIST) (Pioch et al. 2009). Lieberman (2012) used mixed methods to enhance representativeness of an agent. Kott and Corpac (2007) presented the Conflict Modeling, Planning, and Outcomes Experimentation (COMPOEX) that engages many different modeling methods to facilitate better representativeness of large, complex systems.

Expectation of a unique insight. Kott and Corpac (2007) describe cascade reaction as results of interactions between models that can produce an emerging situation that a single model by itself could not. This indicates the purpose of surprising discovery by using the model.

Dimensions and criteria. Different criteria could be applied to justify the usage of multi-method M&S more systematically. For instance, Brailsford and Hilton (2001) focused on technical differences, whereas Lane (2000) focused on conceptual differences. Sweetser (1996) used a structure, mental model, system orientation, role of simulation, and validity as criteria to differentiate between SD and DES methods. Axelrod (2004) provided criteria for choosing modeling methods in relation to a modeler, a user and a method itself. Behdani (2012) characterized SD, DES, and ABM methods in accordance to their ability to represent complexity at micro and macro levels. Lorenz and Jost (2006) have proposed three dimensions that should be aligned in order to choose the suitable modeling approach: purpose, object, and methodology. Chahal (2010) took this idea further to describe and differentiate between SD and DES methods based on methodology, system, and problem perspectives.

Missing consideration of the "why" question. Waltz (2008) briefly presented the strengths of the four major categories of modeling approaches (ABM, SD, BN, and DES) used in COMPOEX, but the lack of discussion about reasoning and justification behind combining these methods should be mentioned. It is a problematic situation to provide the "what", but ignore the "why" questions in methodological reasoning about a multi-method approach.

The explanations for multi-method approach that were found in the literature relate to the complementary nature of methods with the additional need for methods coupling, data availability and usability, skills and preference of a modeler, stakeholder acceptability, expectation of unique insight, enhanced with the very diverse needs related to understanding, credibility, validity, and complexity of models. Investigation of appropriateness of multi-method M&S to represent social phenomena can help the growing trend of trying to incorporate social phenomena into more descriptive simulations (Bhavnani and Choi 2012; Djanatliev et al. 2012; Hoad and Watts 2012; Lieberman 2012; Onggo 2012; Viana et al. 2012; Zulkepli, Eldabi, and Mustafee 2012).

2.2 Is Current Knowledge that Justifies Selection of the Multi-Method Approach in Building Simulation Model that Consist of Social Phenomena Satisfactory?

A social system is a complex and emergent system, with more than one level of analysis and fuzziness of boundaries, leading often to multiple questions when studying it. Additionally, it may also be possible that a simulation model is used purely to find reasonable objectives that could propel the research of the phenomena further. Situations when a study requirements lead to asking questions that pertain to descriptive as well as theoretical aspects of a social phenomenon would require modeling both aspects. It is likely that some M&S methods would serve better in addressing theoretical, and some more descriptive questions. The question is whether two separate models would be needed, or general as well as specific views are acceptable or even desirable in a single multi-method simulation model that aims to represent social phenomena. Chahal (2010) advised to disintegrate objectives allowing a modeler to determine if a multi-method approach is needed. Unfortunately, the ability to find clear boundaries of objectives related to social phenomena may not be always possible. Social phenomena are often intertwined, and assuming an ability to define clear boundaries may be too optimistic. A case where a single question or objective cannot be divided, but still requires a multi-method M&S may be possible. The criteria and logic leading to this option are still unknown, and need to be explored. The other dimension that should be considered in relation to choosing multi-method approach is related to the question of whether we consider studying single phenomenon or multiple phenomena, which then may need to be structured.

Formats for combining methods proposed by Chahal (2010) are presented in a rigid technical phenomena healthcare context, and have limitations to represent social phenomena large scope. This also limits the possibility to generalize model formats. Similarly, it would be naïve to assume that hybrid SD and ABM classes proposed by Swinerd and McNaught (2012) exhaust all possibilities. Possibly a better approach is to develop the guidance for designing a study format without limiting its structure related to methods and system. It may be difficult to define explicitly social phenomenon boundaries. For this reason, the rigidly structured methods cannot support all possible configurations. Because there are already many M&S methods, and the list will most likely grow, it seems impractical to develop one specific multi-method methodology addressing all multi-method simulation formats and study cases. A generic framework for the development of multi-method methodologies seems more interesting and a reasonable approach. For instance, a project intended to use a multi-method simulation model would start with a design of simulation methodology leading to a choice of methods used. A simulation methodology would be specifically tailored to criteria chosen for its development. This would allow for a systemic approach, yet sufficient modeling freedom that does not constrain creativity. The future work on the framework for building multi-method methodologies clearly depends on exploration of reasoning why and when multi-method simulation models are the right choice.

3 PERSPECTIVES ON MIXING METHODS IN SOCIAL SCIENCE

3.1 Introduction

Starting in 1970s, approaches to using mixed methods in social science began to emerge, and "started to blossom at the turn of the century" (Greene 2007, p. 13). Mixing methods in social inquiry could be described as invitations of different mental models into the same inquiry space with plurality of philosophical paradigms, theoretical assumptions, methodological approaches, formal techniques, and with inclusion of subjectivity reflecting the human perceptions. This section uses the purposes of mixing methods in empirical social science and explores their analogies within the M&S domain. This is facilitated by exploration and translation of social science's mixed methods perspectives covered by Greene (2007) into the area of multi-method M&S. For clarity's sake, "mixed method" refers to social science approaches and "multi-method" refers to M&S approaches.

Practical aspects of mixed methods are more difficult than theoretical ones (Greene 2007, p. 101). This may be not so obvious with multi-method simulation models. The development of a multi-method simulation model can be considered difficult, but the theoretical and axiomatic aspects are not as clear as in the case of (social) mixed methods. In mixed method social study, a “wider toolbox” increases flexibility and chances of a broader view of phenomena. Similarly, a researcher engaged in multiple dimensions of building, testing, analyzing of a multi-method simulation model could draw mental models represented differently with each method. Propelling modelers’ generative abilities may be the most important advantage of the multi-method M&S approach. On the other hand, this fact could be very difficult to prove.

3.2 Perspectives on Mixing Methods in Social Science Projected onto the M&S Field

Greene, Caracelli, and Graham (1989) developed a conceptual framework aimed at the mixed method approach. It is based on theoretical principles from the literature with addition of the analysis of 57 empirical mixed-method evaluations. The authors identified five purposes for engaging in a mixed-method approach. Exploration of these purposes could provide important direction for evaluation of the usefulness of multi-method M&S to represent social phenomena, hence justifying its use. The following is a summary of these purposes and their projections reflecting M&S multi-method context. Figure 1 displays some of the ideas covered during the discussion.

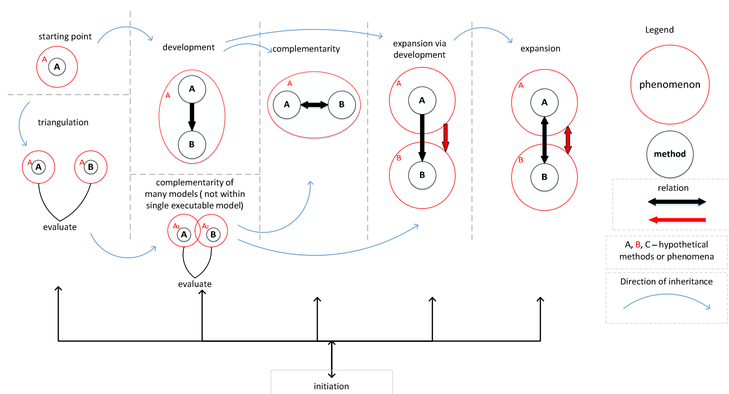

Figure 1: Graphical representation of mixed method social science projected onto multi-method M&S.

Triangulation uses different measures for the purpose of investigation of the same phenomenon with offsetting biases of different methods, with the ability to identify irrelevant sources of variation, observing consistency based on comparison of results from different methods. It captures a phenomenon through different lenses but with the same conceptualization. This has a goal of increased validity and credibility. In the M&S field, this may be conceptualized as building two or more models using different methods, maybe by different parties, to increase the validity of results or to represent phenomenon through different lenses of abstraction (e.g., specific or general). Triangulation could be also considered in the context of different models built with the same method, but this avenue is not part of this research. The main idea behind *triangulation* refers to possibility of the comparison of two or more models, for our consideration developed with different methods. The models are not designed in order to interact together during the model’s execution.

Complementarity focuses on broader, deeper, and more comprehensive facets through additional development, initiation, and expansion of the same complex phenomenon. Different methods are employed because they complement each other. This approach projected onto the M&S field might be translated as the addition of elements or views realized at a different or the same level of analysis by using different methods needed for better representation of a phenomenon for a given purpose. A somewhat similar idea in M&S community can be called a pluralistic perspective and was advocated by Helbing (2010), who wrote that this approach “should lead to a better quantitative fit or prediction than most (or even each) model in separation, despite the likely inconsistency among the models.” (p. 15). Helbing (2010) considered usefulness of different models to represent different aspects or parts of the system (which may overlap) by creation of the analytical structure made of different models that increases validity of the insight. Unfortunately, he did not consider merging models into a single executable model. What follows, a possibility for better usefulness of combined different methods should be considered as a driver for use of combined models. In order to distinguish the *complementarity* purpose for multi-method approach from the *triangulation*, in the M&S field the *complementarity*-based simulation model should be implemented in the form of views that can be integrated, allowing for a more holistic view of the system or phenomenon. Because the focus of this work is the multi-method M&S approach, *complementarity* refers to methods, not models. Two forms can be also distinguished that are important to consider in the M&S field. The first form should consider execution of complementarily viewed parts with different methods within a single model. The second approach focuses on the use of complementary models with separate methods that are not executed together, and used, e.g., via analytical evaluation that provides a more holistic view. Hence, the major difference lies in the level of binding: executable as a single model or not. A tight analytical structure for evaluation of complementary models as proposed by Helbing (2010) fits to triangulated and complementary models that are built with separate or the same methods, because the single executable model built with different methods was not considered. Obviously, there can be many models of phenomenon built with the same method, which relates to a broader human perspectives' complementarity, providing different viewpoints based on each modeler's views and views of many modelers as well. The combination of model, human, and method dimensions creates possible combinations of how one can understand complementarity. Because this work focuses on purposes of the multi-method approaches, the methods' complementarity is given the most consideration.

Development's main idea lies in the sequential alignment of different methods with their inherent strengths, where one method is used to inform and help in the development of the follow up work that employs another method. In M&S, this could mean that an output from the first model represented with one method is used as an input to the second model using a different method. The frequency of updating between methods defines time complexity of this unilateral binding. Other options explaining projection of *development* into the M&S field is the purpose of the systematic increase of the phenomenon understanding facilitated by using different methods at different stages of modeling and validation of a conceptual model with an intermediate method (Balaban, Banks, and Sokolowski 2012). This option would not require methods to be integrated, but be only related by a sequential function in the simulation-based research process. In order to distinguish this purpose from the complementarity purpose it should be assumed that interaction flow (conceptual or numerical) is unidirectional (no feedback).

Initiation induces paradox, contradiction, divergence, dissonance, and disagreement in order to create different perspectives and important insights, and allows for discovering the need for further analysis. It is similar to complementarity but with the concept of looking at a broader scope of disagreement and divergence. In multi-method M&S, initiation may be realized when applied additional different method is leading to contradiction, surprising results, or unexpected insight in comparison to the single method original model. Even if this seems more an effect than a purpose, use of, for instance ABM, in social science is especially focused on *initiation.* Unfortunately, social scientists are in large measure not concerned with the possibility of multi-methods M&S as the additional driver of this effect.

Finally, *Expansion* calls for the use of different methods to capture different phenomena, which extends scope, breadth, and range of the study. It focuses on the use of the most appropriate method for different constructs. In multi-method M&S, this may be represented as the combination of different modeling paradigms to capture different phenomena.

4 DISCUSSION

All of the presented purposes for engaging in a mixed method approach in empirical social science have feasible projections to simulation-based studies. The focus of this work is multi-method simulation models where methods exchange data during their execution, especially involving bi-directional (with feedback) information flow. This narrows the scope of the exploration and the need of the consideration to those purposes for mixing methods that reflect this research boundary. The purpose of *development* is limited to the sequential character and could be derived in the M&S context from the purpose of *complementarity* or *expansion*. The purpose of *triangulation* is limited to the use of methods separately, e.g. for validation purposes or comparison. *Triangulation* of method is often valuable, but it is being discarded from further consideration here, because this study focuses on employing multiple interacting methods within a single simulation model. One the one hand, the purpose of *initiation* seems applicable to all the other purposes as the desirable study outcome. However, it is a very abstract concept that is difficult to represent graphically because it exists at human dimension.

The exploration of emergent phenomena can be often surprising, and social scientists are engaged with simulation techniques to get that "wow" moment that could be described by the *initiation* purpose. Most likely, the origination of the study directs the use of multi-method M&S by purposes of complementarity, development, or expansion that could lead to initiation. On the other hand, it would be problematic to assume that multi-method approach would bring constructive disagreement from the beginning of the model design. The purpose of *initiation* needs further research in M&S science, especially because it can be considered a higher-level purpose for explaining social phenomena, with or without multi-method simulation models. The above discussion for purposes of multi-method M&S based on purposes for mixing methods provided by Greene (2007) will be narrowed temporarily to *complementarity* and *expansion*.

The *complementarity* and *expansion* elements as purposes for using a mixed method approach in social science are relevant when projected onto the reasoning for the use of multi-method M&S. On the other hand, both are high-level purposes that need to be also refined with M&S dimensions. In order to justify the choice of using multi-method M&S in a given study context, the multi-method approach should show some sort of superiority or higher need over the single method model with specified criteria. It should be shown that combinations of models developed with the same method could not provide the same results as obtained through *complementarity* or *expansion* purposes. For instance, the need of *expansion* of a model to embed additional phenomena can lead to requirements identifying multi-method M&S as the preferred approach, thereby prohibiting the choice of nested model using a single method as sufficient to capture multiple phenomena. Similarly, additional insight into phenomenon through refinement or generalization should be shown impossible in the single method approach. Obviously, these cases should not be considered as a rule, but as proof of a concept showing the need for a multi-method approach in some cases. Hence, *expansion* or *complementarity* could take the multi-method route, but depending on some additional dimensions or criteria that would have regarded the single approach as inferior. The purpose of *expansion* and *complementarity* can sometimes become vague depending on subjective definition of phenomena. When analyzing Green's definition, the *expansion* could not be conceptualized as *complementarity* purpose because it is directed toward additional phenomena. On the other hand, when considering concept of M&S methods' complementarity only, this difference disappears because a phenomenon is not considered as unit of analysis to distinguish between *complementarity* and *expansion* reasons. From the M&S perspective, it is possible that different methods complement each other in order to expand the simulation model inward or outward through refinement and generalization. In this context, complementarity is required to expand a view on a phenomenon or extend a model with a new phenomenon. This perspective invites both inductive and deductive scientific research approaches into a simulation model. It does not seem sufficient to say that different methods are always required, but they may be required to complement each other. With this in mind, it is possible to combine social science purposes of *complementarity* and *expansion* perspectives and M&S's method complementarity perspective to describe *complementarity of methods* as the purpose of directing the expansion of phenomena studied inward (generalization and refinement), or directing the expansion of a study outward to combine different phenomena, using different methods within one simulation model. Multiple inward and outward expansions are possible within a single multi-method simulation.

The graphical representation of high-level dimensions that were discussed in this research is proposed in Figure 2. Derived dimensions influence reasoning about justification for the multi-method approach and provide a road map for future research related to methodological aspects that should be considered.

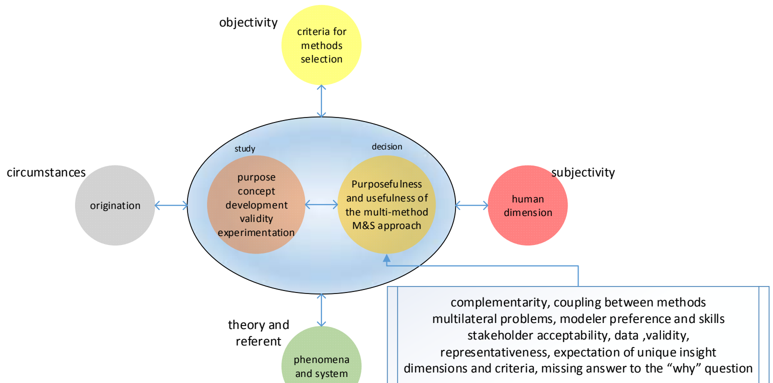

Figure 2: Dimensions for considering purposefulness of multi-method approach in representation of social phenomena.

The flowchart presented in Figure 3 proposes a structure of decision phases that mimics choosing between single and multi-method approaches.

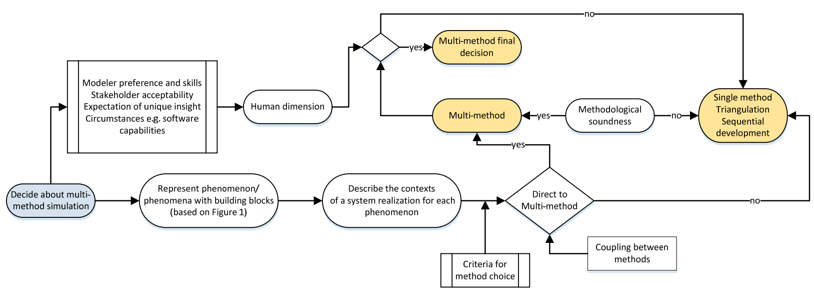

Figure 3: Guidelines for decision and justification of the multi-method approach in representation of social phenomena.

This aims at facilitation of a more systematic approach to evaluation of the purposefulness of using the multi-method M&S approach. The flowchart offers a structure to the decision-making process for determining the need for the multi-method approach in the context of social phenomena representation. The decision to use a multi-method M&S approach can be determined by three major dimensions: 1) structures of phenomena (Figure 1) and system, 2) methodological soundness, and 3) a human dimension. Structures of phenomena and system that direct toward more than one coupled method should be supported by criteria for the method choices. A set of criteria depends on methods considered, and it should be able to expose methods' uniqueness. This can help to indicate the need for a multi-method M&S approach. The criteria for method choice consider features of methods and a system in different contexts. For a detailed discussion about possible criteria, refer to Lorenz and Jost (2006), Axelrod (2004), Chahal (2010), Lane (2000), Schieritz and Milling (2003), Helal (2008), Finnigan (2005), and Behdani (2012). The assumptions that each method carries can be contradictory when mixing methods in a specific methodological context, hence methodological soundness should be satisfied by making sure that combined assumptions of methods do not interfere with a methodology that is undertaken (i.e., abduction risk (Lorenz and Jost 2006)). Additionally, a final decision is made based on the higher-level reasons related to the human dimension. The human dimension reflects preferences and skills of a modeler, stakeholder acceptability, expectations of unique insight (the purpose of *initiation*), and other subjective elements and circumstances e.g. software capabilities.

5 CONCLUSIONS AND FUTURE WORK

This paper has explored the problem of justification for the use of multi-method simulation models, displaying current reasoning and perspectives as seen within the M&S community and based on views adapted from social science. Both viewpoints on purposes for mixing methods provide an initial understanding of the ingredients for inferring purposefulness of the multi-method approach in the context of social phenomena representation. The structure of the decision phase for choosing between single and multi-method approach was proposed and briefly described, providing a road map for future research related to methodological aspects of the multi-method approach.

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