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SOFT OR APPROACHES IN PROBLEM FORMULATION STAGE OF A HYBRID M&S STUDY

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ABSTRACT

A simulation study consists of several well-defined stages, e.g., problem formulation, model implementation and experimentation. The application of multiple techniques in the model implementation stage is referred to as *hybrid simulation,* which we distinguish in this paper from a *hybrid M&S study,* the latter referring to studies that apply methods and techniques from disciplines like Operations Research, Systems Engineering and Computer Science to one or more stages of a simulation study. We focus on the first stage of a simulation study (and by extension a hybrid M&S study), viz., eliciting the system requirements, and conduct a review of literature in Soft Systems Methodology for healthcare operations management. We discuss the potential for the use of *Qualitative System Dynamics* as an additional soft OR method, complementing (rather than supplanting) existing approaches, which can further aid the understanding of the system in the problem formulation/conceptual modelling stage of a Hybrid M&S study.

1 INTRODUCTION

Simulation methods enable stakeholders to analyze and evaluate strategies for effective management of complex systems, providing an experimental test bed or environment for different stakeholders to assess the effectiveness of putative, sometimes emergent policies. There are two separate areas of investigation which they aid, namely policy investigation and cognitive investigation (after Powell and Coyle 2005). By policy investigation we mean the exploration of the (predicted) effects of emergent, developing policy by interested parties. Here the scope of the system under investigation, including performance measures, is held constant; or is at least undebated. This allows exploration of a variety of policy options, which may be operational or strategic in nature, aimed at managing the undebated system to produce optimal, desirable or at worst acceptable results. In the simplest case there is one, dominant system owner who has the authority, *de iure* or *de facto* to represent any other stakeholders in assessing system output. More often there are a number of stakeholders vying for control over the system performance through the application of the candidate policies.

In many cases, and in health systems as an example, the stakeholder set not only disagrees about the desirability or optimality of system outputs, but about the very definition of the system under scrutiny. In most cases these disagreements are cognitive in nature since the divergence among the stakeholders' perceptions of the system are shaped through their unique experiences of working with the system. In other cases the differences are structural in the sense that different stakeholders will define the system itself or parts of the system differently from their points of view (and in rare cases existential), but we label them here collectively as requiring *cognitive* exploration in contrast with the need to explore policy options. In both cases simulation can assist in that exploration, but the cognitive case requires, we submit, a degree of extra support.

Health systems have particular characteristics in terms of requirements capture, including an unavoidable dissonance between the ontologies of the simulated system (positivist, single reality) and that of the surrounding socially constructed, multiply-defined recipient and policy contexts. Within healthcare studies, simulation techniques such as Monte Carlo Simulation (MCS), Discrete-Event Simulation (DES), System Dynamics (SD) and Agent-based Simulation (ABS) are in wide use (Brailsford et al. 2009; Katsaliaki and Mustafee 2011). Frequently, however, these techniques have been applied in isolation one from another, in dissonance with good system practice, (Jackson 2000) which stresses the usefulness of hybrid methods in order to overcome the unavoidable limitations of any single approach. The search for the best possible representation and analysis of the system under scrutiny has, then, led to an increasing number of studies that combine simulation techniques/Operational Research methods. These combined methods allow application of multiple techniques in the *model implementation stage* of a simulation study, thereby enabling synergies across techniques to engender improved insights. However, while this is a critically important phase, a M&S study comprises several other well-defined stages (Maria 1997), for example, problem formulation stage/conceptual modelling (Robinson 2011), data collection, validation and verification, model execution, output data analysis and recommendations. It is, then, appropriate to explore the use of multiple techniques in the wider perspective of a study. In this paper we distinguish between *hybrid simulation* and a *hybrid M&S simulation study*, the latter referring to studies that apply methods and techniques from disciplines like Systems Engineering, OR and Computer Science to one or more stages of a simulation study (Section 2).

Next, we focus at the starting point of a M&S/hybrid M&S study with the objective of identifying commonly used multi-disciplinary techniques in the problem formulation/conceptual modelling stage. Through a quick review of literature we were able to identify the application of systems engineering approaches and tools (e.g., SysML: Systems Modeling Language – Eldabi et al. (2010)), problem structuring methods (PSM/soft OR) (e.g., *Soft Systems Methodology* – Lehaney and Paul (1994, 1996), Kotiadis, Tako, and Vasilakis (2014); *Group Model Building* – Bérard (2010) and concepts from information systems (e.g., Issue Maps/Issue-Based Information System (IBIS) – Eldabi et al. (2010)) in the problem formulation phase. Our review of literature also revealed the prominence of the Soft Systems Methodology (SSM) (Checkland and Scholes, 1990) in healthcare studies in general, especially those that involved multiple stakeholders in the decision making stage. We therefore considered it pertinent to conduct a literature review on SSM in the context of its application in the wider area of healthcare operations management (i.e., we were not restricted to SSM-M&S studies alone). The methodology for the review is described in Section 3; the initial findings are presented in Section 4 .

The literature review identified the lack of use of complementary soft OR techniques (which could potentially be used together with SSM) in the problem formulation stage of a hybrid M&S study. In Section 5 we critique this segmented approach and argue the need for soft OR techniques that not only provide insights to the 'wicked or 'messy' problems but which further support the development of the quantitative simulation models and could potentially be used together with SSM. In this line of thought we discuss *Qualitative system dynamics (QSD)*, a modeling and analysis technique which bridges the numerical, positivist requirements of simulation and the socially constructed world of its surrounding context, is a subset of System Dynamics (SD), a well-known system representation and analysis method (Sterman, 2000). In addition to its almost ubiquitous numerical form, SD has of recent years expanded its embodiment in to a qualitative form (Powell and Coyle, 2005) which in its analytical phase replaces the detailed simulation-type system output with a structural analysis, concentrating on predicting desirable managerial interventions by direct consideration of the dominant dynamics of the system in focus. As such we find its ability to incorporate system knowledge other than that of a numerical nature highly conducive to the requirements capture of simulations in the present context.

The concluding section of our paper (Section 6) presents future work and draws the paper to a close.

2 HYBRID M&S STUDY

The existing literature in hybrid simulation comprises mainly discursive papers comparing different techniques (e.g., Brailsford, Desai and Viana 2010), together with case studies, integration frameworks and studies that have used these frameworks/framework extensions to create hybrid models (e.g., Viana et al. 2014, Chahal and Eldabi 2010, Chahal and Eldabi 2008; Zulkepli, Eldabi, and Mustafee 2012). Specific techniques that have been applied include, the combined application of SD and DES (Viana et al. 2014; Zulkepli, Eldabi, and Mustafee 2012; Chahal 2010; Chahal and Eldabi 2008), hybrid M&S using ABS, SD and DES (Djanatliev and German 2013; Viana et al 2012), combined application of ABS and load plan construction heuristics (Mustafee et al. 2012), hybrid simulation with loosely coupled SD and agent-based models (Djanatliev et al 2012) and application of integer programming with simulation (Lee et al. 2012). The majority of these papers focus on the *model implementation* phase of a simulation study.

Our review of literature provides evidence of the application of methods and techniques from disciplines like Computer Science, Systems Engineering, OR, Information Systems and Distributed Computing to the various other stages of a M&S study. For example, in *problem formulation stage* approaches from soft OR, systems engineering and information systems have been used (refer to the previous section for specific example). For faster simulation execution in the *experimentation stage* authors have used techniques from computer science, e.g., General-Purpose computing on Graphics Processing Units (GPGPUs) (Perumalla 2006; Park and Fishwick 2010), parallel and distributed simulation (Lendermann, Gan, and McGinnis 2001; Mustafee et al. 2009) and distributed computing solutions like simulation execution over desktop grids (Mustafee and Taylor 2009; Taylor et al. 2011) and, in the future, cloud computing resources. *Model formalisms* based on Discrete Event System Specification (DEVS) (e.g., Dynamic Structure Discrete Event System Specification (DSDEVS) - Barros 1995) and meta-modelling using UML (Traoré 2003) have been used. Further, it is arguable that statistical and computing approaches presently being developed in the field of business intelligence, big data and analytics (Demirkan and Delen 2013) could be applied *in M&S study stages pertaining to collection of input data and output data analysis*.

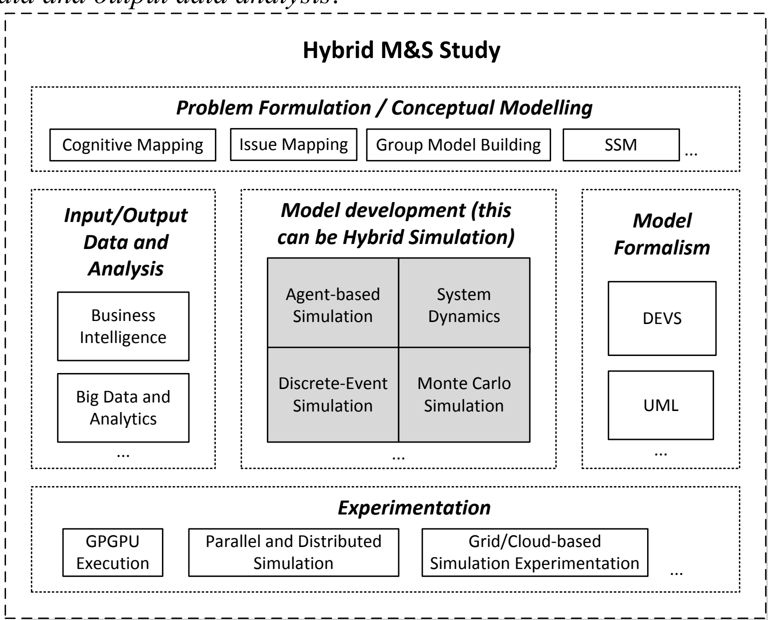

Figure 1: Conceptual representation of a Hybrid M&S study (… denotes other methods).

The discussion above indicates the multi-disciplinary nature of a M&S study. Unlike hybrid simulation that focuses on individual M&S techniques in the *model implementation stage*, a **hybrid M&S study** recognizes and deploys the use of inter-disciplinary methods at various other stages of a simulation study. Figure 1 shows our conceptualization of a hybrid M&S study, identifying a number of inter-disciplinary methods that have been used (or can potentially be used) in specific stages of a M&S study. Our conceptual representation is not exhaustive (indeed not all stages of a simulation study are depicted;

stages pertaining to input data and output data analysis have been combined; model formalism has been introduced as a stage). Figure 1 includes the *model development stage* in the center and depicts four simulation techniques which can be used either in isolation (as in the conventional studies) or can be combined to implement a hybrid simulation. The techniques are represented in grey boxes so as to distinguish them distinguish them from inter-disciplinary methods (in white boxes) that are/can be applied to stages other than simulation model development, such as *Model Conceptualization*, *Input Data, Output Data Analysis*, *Simulation Experimentation* and *Model Formalism*.

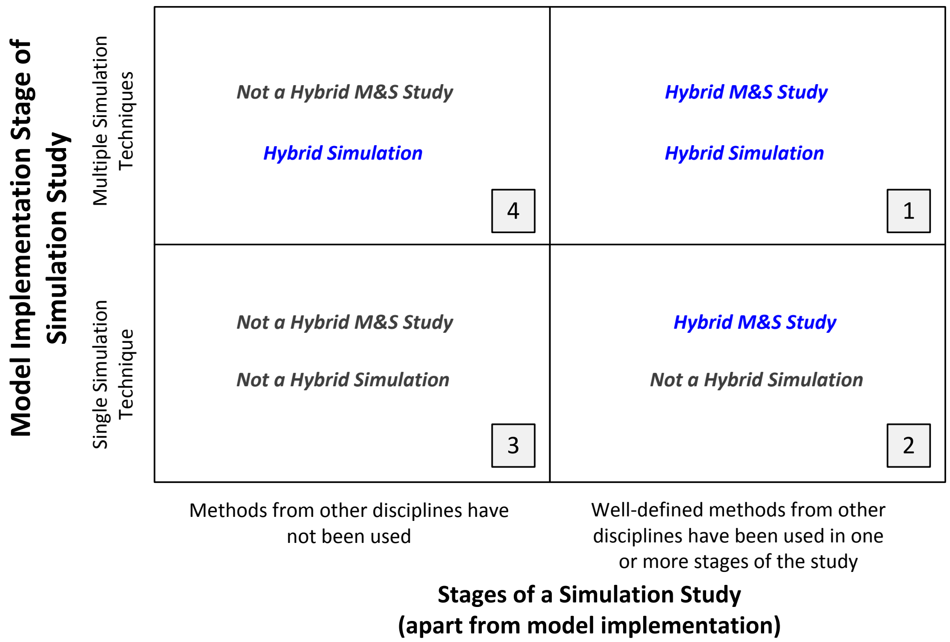

Figure 2: Hybrid M&S study *versus* Hybrid Simulation.

Figure 2 clarifies the differing scope of hybrid simulation vis-à-vis hybrid M&S. It shows that a hybrid M&S simulation study will apply well-defined methods from disciplines outside M&S in one or more stages of the study (Quadrant 2; Figure 2). A hybrid M&S study will also be a hybrid simulation when multiple simulation techniques have been used in the model implementation stage (Quadrant 1; Figure 2). However, an implementation of hybrid simulation without the application of inter-disciplinary methods in the wider study will disqualify it from being a hybrid M&S study (Quadrant 4; Figure 2). Quadrant 3 represents the traditional studies which have used only one modelling technique and which in methods from other disciplines have not been used.

3 METHODOLOGY

In order to identify papers for our methodological review of literature we conducted a search using the ISI Web of Science™ (WOS) database. WOS is one of the largest databases of quality academic journals and provides access to bibliographic information pertaining to research articles published from 1900 onwards (for Science Citation Index Expanded). It indexes approximately 9800 high impact research journals spread across more than 200 disciplines. Further, WOS now includes two conference proceedings citation databases, for Science (CPCI-S) and Social Science & Humanities (CPCI-SSH) respectively, which indexes the most significant academic conferences (from 1990 onwards) in a wide range of disciplines. We used various combinations of keywords and varied parameters like specific WOS databases used and timespan for the search, reviewed the retrieved results and subsequently decided on the specific search parameters for the study. We used the keywords (***"soft system* method*"***) AND (***health****), with * being the wildcard character which allowed us to use the keyword derivatives in the search condition, to conduct a *topic search* on title, abstract, author keywords and keyword plus®. All WOS databases were included in the search. We did not restrict the year of publication and selected timespan as 'all years'. It is to be noted that we did not use the acronym SSM since our preliminary searches using this keyword resulted in a number of irrelevant hits. We subsequently tried to apply a search condition which would restrict results to SSM in the context of healthcare, however, this did not produce the desired outcome since several papers on Superficial Spreading Melanoma (which is the most common form of skin cancer) were retrieved.

Our search criteria retrieved a total of 68 papers for the initial analysis. The next stage involved reading the abstracts and identifying papers that applied SSM in the context of healthcare operations management. Thus we excluded, for example, four papers that used SSM for designing healthcare information systems (including papers on eliciting user requirements for such systems) and further two papers on using SSM for planning and management of information security in healthcare, one paper on racial equality in health provisions, one paper on SSM-based evaluation of electronic library for healthcare professionals and one paper on using SSM to identify impact and barriers to information access and use in health. 49 papers were selected subsequent to the abstract reading phase of the study and this comprises the corpus of scholarly articles for the literature review part of this paper.

4 REVIEW OF LITERATURE IN SSM

In this section we present some preliminary findings from our literature review. A study focusing specifically on the findings of the review will be the subject of a future publication. We have collected information pertaining to several variables from the 40-odd papers that we have presently reviewed (we were unable to access full-text for some of the papers in our underlying data set). The variables captured included, the aim of the study, the specific application context, the country in which the SSM study was conducted, whether SSM was used as per the original methodology (e.g., the seven stage SSM process; (Checkland 1981)) or extensions/improvements to the methodology were proposed, software used (e.g., for the purposes of data analysis, illustration of 'rich pictures'), the SSM concepts and tools that were used (e.g., holons, 'rich pictures', root definition, CATWOE, conceptual model, etc.), the primary stakeholders, the composition of the stakeholder group who contributed to the development of the conceptual model(s) and/or who were responsible for recommending and/or implementing the results through 'action research', outcome of the study/findings, how SSM contributed to the outcome of the study, and whether the SSM study included elements of mixed methodology (considering the scope of this paper, this variable is of particular interest to us and will be further explored). Further to this, for studies which had used SSM in the context of M&S, we collected variables describing the type of simulation model (e.g., DES, SD) and whether the paper included the implementation aspects of the aforementioned model.

In this paragraph we outline the composition of our underlying dataset of 49 papers which were methodologically selected for the review. Approximately 80% of these papers (40 papers) have been published in journals (one exception to this is a poster which was published in the journal *Tropical Medicine & International Health*); the remaining nine papers were published as conference proceedings with *Winter Simulation Conference* accounted for six papers. In relation to journals, 11 articles have been published in the *Journal of the Operational Research Society*, followed by three articles each in the *Journal of Advanced Nursing* and *Health Services Management Research* (refer to Table 1).

It is to be noted here that our dataset included review papers (paper number 10 and 38 – see Table 1), papers which proposed methodological extensions to SSM (17, 48) and frameworks (28), discussion and viewpoint papers (27, 41), and empirical papers reporting on SSM studies. With regard to the latter, most of the studies were based in the UK (20 studies); this is hardly surprising since the founder of SSM (Peter Checkland) and his colleagues were based in Lancaster University (UK) and spend decades working on approaches that finally culminated in the formalization of SSM as a problem structuring approach.

Further, it is widely recognized in the international OR/M&S community that Britain has significant strengths in 'soft OR' (and applications in healthcare) (EPSRC/ESRC, 2004). Studies that were conducted outside the UK include, three studies in USA (in Chicago - 31, multiple regions - 38, 35), one study each in Australia (State of Victoria) (18), South Africa (KwaZula-Natal) (19), Ireland (23), Norway (33), Brazil (36), Greece (37), Iran (39) and Canada (41).

Next, a few studies have proposed an extension to SSM. (12) introduce SSM+ that consists of 16 stages and is positioned for the use of policymakers, clinicians and managers in health care circles. (32) propose the extension of SSM's graphical elicitation with graphical modelling approaches from other disciplines. (40) propose the inclusion of Performance Measurement Model (PMM) in SSM. However, the majority of the studies have either 'religiously' adhered to the seven stage process of SSM (e.g., 25, 20) or have adopted a subset-of SSM concepts and tools (e.g, there are references to using 'SSM as a guiding principle', using 'SSM-inspired tools', using 'modified version of the methods from SSM'). Our dataset also consisted at least eight papers that claimed to have conducted a SSM-study, however, the process itself was not adequately described/the use of SSM was not apparent, and in some cases only a general reference to SSM was made. It is arguable that a couple of these studies used the term SSM as an umbrella term since their case studies included multiple stakeholders with a need to form consensus/cooperatively implement actions. We had two papers in which a plan for action was proposed, i.e., the study was not yet implemented and the authors articulated the future course of action (44, 35).

Out next analysis is on context of application or the specific theme of study. Some of the themes we identified included, use of SSM for professional and organizational learning – including development of curriculum in health sciences (15, 21, 33), evaluation of decision-making in inter-agency/intra-agency, interdisciplinary/unidisciplinary teams (16, 34), use of SSM for improving patient care (18, 23, 30), critical systems inquiry into the complexities of implementation a healthcare provision (19, 20, 25), use of SSM for conceptual modelling (32), the use of SSM for multi-agency planning of disaster (12), etc.

Our final analysis focuses on the complementary methods that have been used together with SSM in the development of conceptual models (it is to be noted that the development of the conceptual model is the fourth step in the seven stage SSM process; for a M&S study that uses SSM, the SSM conceptual model informs the conceptual model of the simulation to be developed). Of the 49 studies in our literature review, we could find evidence of multiple methods in only a handful of studies. The study by (16) advocated two approaches for evaluating the success of integrated, multiprofessional healthcare teams in the UK – SSM and a *pluralistic framework*; however, these approaches were not used together but in two separate case studies. Thus it is arguable that this particular study has not implemented a mixed methodology. The study by (19), however, contributes to the growing literature on the combination of systems methods by illustrating how conceptual models of SSM's purposeful human activity were constructed from the participatory use of *Concept Maps* and *Sign-graph Diagrams*. The study by (26) has used SSM with a *project management* framework (PRINCE2); this is an example of using a concept from Operations Management (project management) together with soft OR. (31) has used *social ecological model* together with SSM, wherein the former was used to understand the interaction between various personal and environmental factors, and the latter helped "understand the multiple perspectives of stakeholders which in this case were also a source of resistance to change and conflict." In (34), appreciative inquiry was combined with SSM to form an evaluation approach that was designed to capture individual as well as organizational learning. In (35) the authors developed models of workflow and information flow using *Hierarchical Task Analysis* and SSM. Thus, only a handful of studies have explored the use of complementary approaches that can be used together with SSM, and this, we believe, is an area of future research.

Table 1: Papers selected for the literature review.

Sn	Authors (Year)	Title of the Paper *(Source Title)*
1	Lauri, S (1992)	Using a computer simulation program to assess the decision-making process in child health care *(Computers in Nursing)*
2	Lehaney, B., et al. (1994)	Using soft systems methodology to develop a simulation of out-patient services *(Journal of the Royal Society of Health)*
3	Wells, JSG (1995)	Discontent without focus? An analysis of nurse management and activity on a psychiatric in-patient facility using a 'soft systems' approach *(Journal of Advanced Nursing)*
4	Hindle, T., et al. (1995)	Developing a Methodology for Multidisciplinary Action Research: A Case Study *(JORS)*
5	Lehaney,, B., et al. (1995)	Simulation modelling for resource allocation and planning in the health sector *(Journal of the Royal Society of Health)*
6	Lehaney, B., et al. (1996)	The use of soft systems methodology in the development of a simulation of out-patient services at Watford General Hospital *(JORS)*
7	Hernando, S (1997)	Promoting library services to qualified nurses: towards a market-led approach *(Health Libraries Review)*
8	Connell, NA., et al. (1998)	Patient-centred performance monitoring systems and multi-agency care provision: a case study using a stakeholder participative approach *(Health Services Management Research)*
9	Hindle, T., et al. (1998)	Specialty location decisions in the reformed NHS: a case study *(Health Services Management Research)*
10	Jun, JB., et al. (1999)	Application of discrete-event simulation in health care clinics: A survey *(JORS)*
11	Lehaney, B, et al. (1999)	A case of an intervention in an outpatients department *(JORS)*
12	Gregory, WJ., et al. (2000)	Planning for disaster: developing a multi-agency counselling service *(JORS)*
13	Loo, GS., et al. (2001)	A Soft Systems Methodology model for Clinical Decision Support Systems (SSMM-CDSS) *(Workshop on Database & Expert Systems Applications)*
14	Connell, NAD (2001)	Evaluating soft OR: some reflections on an apparently 'unsuccessful' implementation using a Soft Systems Methodology (SSM) based approach *(JORS)*
15	Clarke, CI., et al. (2001)	Professional and organizational learning: analysing the relationship with the development of practice *(Journal of Advanced Nursing)*
16	Cook, G., et al. (2001)	Decision-making in teams: issues arising from two UK evaluations *(Journal of Interprofessional Care)*
17	Braithwaite, J., et al. (2002)	Introducing soft systems methodology plus (SSM+): why we need it and what it can contribute *(Australian Health Review)*
18	O'Meara, P (2003)	Would a prehospital practitioner model improve patient care in rural Australia? *(Emergency Medicine Journal)*
19	Luckett, S., et al. (2003)	A critical systems intervention to improve the implementation of a district health system in KwaZulu-Natal *(Systems Research and Behavioral Science)*
20	Kalim, K., et al. (2004)	The role of soft systems methodology in healthcare policy provision and decision support *(Conference on Systems, Man & Cybernetics)*
21	Stokes, PJ., et al. (2004)	Information-seeking behaviour of nurse teachers in a school of health studies: a soft systems analysis *(Nurse Education Today)*
22	Fahey, DK., et al. (2004)	Applying systems modelling to public health *(Systems Research and Behavioral Science)*
23	Wells, JSG (2006)	Hospital-based industrial therapy units and the people who work within them - an Irish case analysis using a soft-systems approach *(Journal of Psychiatric & Mental Health Nursing)*
24	Kotiadis, K., et al. (2006)	Combining PSMs with hard OR methods: the philosophical and practical challenges *(JORS)*
25	Kalim, K., et al. (2006)	An illustration of whole systems thinking *(Health Services Management Research)*
26	Checkland, P., et al. (2006)	Process and content: two ways of using SSM *(JORS)*
27	Kuljis, J., et al. (2007)	Can health care benefit from M&S methods in the same way as business and manufacturing has? *(WSC)*
28	Eldabi, T., et al. (2007)	Towards a framework for healthcare simulation *(WSC)*
29	Sachdeva, R, et al. (2007)	Mixing methodologies to enhance the implementation of healthcare operational research *(JORS)*
30	Reed, Jan, et al. (2007)	Specialist nurses for older people: implications from UK development sites *(Journal of Advanced Nursing)*

31	Suarez-Balcazar, Y, et al. (2007)	Introducing systems change in the schools: the case of school luncheons and vending machines *(American Journal of Community Psychology)*
32	Kotiadis, K., et al. (2008)	Conceptual modelling: Knowledge acquisition and model abstraction *(WSC)*
33	Fougner, M., et al. (2008)	I had a rich picture ... : Insights into the use of "soft" methodological tools to support the development of interprofessional education *(Journal of Interprofessional Care)*
34	Carr, Susan M, et al. (2009)	Leadership for health improvement--implementation and evaluation *(Journal of Health Organization and Management)*
35	Unertl,KM, et al. (2009)	Describing and Modeling Workflow and Information Flow in Chronic Disease Care *(Journal of the American Medical Informatics Association)*
36	Tako, A., et al. (2010)	A participative modelling framework for developing conceptual models in healthcare simulation studies *(WSC)*
37	Eldabi, T., et al. (2010)	Model driven healthcare: Disconnected practices *(WSC)*
38	Mingers, J., et al. (2010)	A review of the recent contribution of systems thinking to operational research and management science *(EJOR)*
39	Ribesse, N, et al. (2011)	Technical assistance for health system strengthening in fragile state: learning from experiences through systemic approach *(Tropical Medicine & International Health)*
40	Dalkin, SM, et al. (2012)	Understanding integrated care pathways in palliative care using realist evaluation: a mixed methods study protocol *(BMJ OPEN)*
41	Barra M., et al. (2012)	Using a Soft Systems Methodology framework to guide the conceptual modeling process in discrete event simulation *(WSC 2012)*
42	Sgourou, E., et al. (2012)	Using Soft Systems Methodology as a systemic approach to safety performance evaluation *(Symposium on Safety Science & Technology)*
43	Hodges, S., et al. (2012)	If We're Going to Change Things, It Has to Be Systemic: Systems Change in Children's Mental Health *(American Journal of Community Psychology)*
44	Heyrani, A., et al. (2012)	Clinical governance implementation in a selected teaching emergency department: a systems approach *(Implementation Science)*
45	Kotiadis, K, et al. (2013)	Using a model of the performance measures in Soft Systems Methodology (SSM) to take action: a case study in health care *(JORS)*
46	Price, M., et al. (2013)	Provider connectedness and communication patterns: extending continuity of care in the context of the circle of care *(BMC Health Services Research)*
47	Sinclair, E., et al. (2014)	Developing stroke-specific vocational rehabilitation: a soft systems analysis of current service provision *(Disability and Rehabilitation)*
48	Kotiadis, K., et al. (2014)	A participative and facilitative conceptual modelling framework for discrete event simulation studies in healthcare *(JORS)*
49	Vandenbroeck, P., et al. (2014)	Recommendations for the organization of mental health services for children and adolescents in Belgium: Use of the soft systems methodology *(Health Policy)*

5 COMPLEMENTARITY REQUIREMENTS

It is clear from our review of the literature that there is little evidence of the mobilization of complementary soft OR techniques in the problem formulation/conceptual modelling stage of the hybrid M&S approach. There are dangers in such a segmented approach, particularly in respect of the need for inclusion in the model building (at the requirements capture stage) of:

a) *The maximally available information about the behavioural dynamics of the system under consideration*, particularly as the very *raison d'etre* of a simulation (at least in this context) is accurately to extrapolate the dynamic effects of system mechanics as conditioned by the proposed policies being assessed. It would seem wise at the requirements capture stage to maximize this input and indeed to confirm anticipated dynamics with informed parties. If this is done in an explicit manner there is an additional advantage of being able to validate, together with the stakeholder group, the functional behaviour of the simulation on which the whole assessment turns.

b) *The value perspectives of stakeholders other than the system owner* in respect of the benefits or otherwise of the results of the simulation. At first glance it may seem that the multiple valuation of system outputs can be respected *ex post facto*, by giving voice and weight to the system outputs in the weighing of the benefits of the proposed policy or policies. To some extent this can be done, but there is a danger that in declaring and designing the output representations within the simulation, that implicit valuations are made inadvertently, rendering less visible, or even invisible, factors valued by a stakeholder group which happens to be under-represented in the requirements capture process. To decode; modelers run the risk of ignoring the legitimate valuations of interested but silent parties.

c) *Differing definitions of the system in focus.* Conventional requirements capture processes and techniques are focused on the establishment of a single simulation definition, not least because this makes subsequent model-building easier. While clarity in the simulation definition is much to be valued, work in a variety of embodiments of the soft system philosophy (Checkland, Jackson, Oliga, Coyle …) shows that the single clarified reality of a model representation is often, in fact, a misrepresentation, an over-simplification of a multiple reality produced by the varying, equally valid cognitions and ontologies of stakeholders. Again, to decode: modelers run the risk of assuming that while various stakeholders may have different valuations of system outputs, that they nevertheless agree on the definition of the system each is trying to optimize. This is a risky assumption; the various valuations of stakeholders often lead them into differing cognitions of the system and therefore of its definition. At best the single simulation definition is the result of the interplay of power and communicative capacities of the stakeholders. Now, the nature of the simulation component of the overall assessment system is such that a single requirement (definition of the simulation) is needed at any one time, so that the multiple stakeholder definitions of the system must be dealt with accordingly. There are two options: one is to reconcile differences in system definition among the stakeholders and the other is to run variations of the simulations to reflect the varying 'flavours' of system perceived by the atkeholders. In respect of the reconciliation approach, while this is much to be favoured in terms of the necessary resources applied to simulation (only one simulation is needed) we note that the resolution of stakeholders' views may be different during the requirements capture phase from the policy assessment phase. This adds further weight to the need for an overall assessment process which allows for policy consequences to be included in the early stages of simulation requirements capture.

These perspectives on the plural, even arbitrary nature, of the social and political contexts surrounding a Human Activity System (HAS) (Checkland 1981), of which health systems are clear examples, are, of course, widely offered. There is a clear ontological disparity between the hard, positivist, physical reality of, for example, a supply chain and the socially constructed, politicized, multi-perspective view of the degree of benefit provided by a health delivery system. In fact the whole issue of the reconciliation of these ontologies can be argued to be the concern of the whole corpus of work known as soft OR (Ulrich, 1988; Checkland, 1981; Mingers, 2009). The clash of ontologies, then, is well-known and therefore what is worthy of note here is that there is so little practical mobilization of this corpus of soft OR methods ***directly*** into the world of simulation, particularly at the requirements capture stage, particularly when the influence of SSM and Strategic Options Development Analysis (SODA) (Eden and Ackermann 2004) being particularly effective broad cognitive and problem solving tools, is so great within health system studies. The explanation, we assert, lies in the level at which systems in focus are treated by the soft OR methods. The strength of these approaches are in their capacity to treat the broad problem in a broad manner. It is not their objective to make precise the mechanics of the underlying system which is the legitimate and complementary focus of the simulation. We hasten to add that this shortcoming, seen from the point of view of the simulation worker, should not be seen as a criticism of the soft OR arsenal, any more than a field gunner can be criticized for not being a sniper, but from the point of view of achieving helpful, applicable, representative requirements in which basis simulations can be constructed, an interlocution between the powerful but broad, multivalent and plural structures of soft OR and the precise, but narrowly defined structures of simulation would appear highly desirable.

The three issues detailed above provide some basis for declaring the characteristics of a complementary approach through which simulation requirements analysis, particularly in the health studies area, can be improved. It needs to be able to

a. Represent and capture expert knowledge of expected system dynamics
b. Represent and capture available expert knowledge of the system structures underlying those dynamics

c. Allow the co-existence of alternative/conflicting evaluations of system behaviour
d. Allow the co-existence of alternative/conflicting system structures

While a number of the well-known techniques of soft OR, including SSM, SODA (Eden, 1989), drama theory, scenario planning, general causal mapping, theory of constraints and benefits modeling (Vidal, 2005) provide very powerful insight into the nature and characteristics of complex problems (often referred to as 'wicked or 'messy' problems they invariably do so not by detailed modeling of the dynamics of a system (as in simulation and quantitative Systems Dynamics) but by more discursive, verbal, often diagrammatic representations. Two stand out from the field in respect of their ability to support directly the simulation activities of which his appear is the focus. These are SODA's cognitive mapping and QSD, the qualitative form of SD, and particularly the variation known as Qualitative Politicised Influence Diagrams (QPID) (Liddell and Powell 2005). We do not reject SODA as a basis for requirement capture here, but offer the observation that because of QSD's provenance as emerging from the corpus of quantitative SD, it has a natural structural connection with the vocabulary and representation methods used by SD to scope and specify its form of simulation, and hence provides a natural interface with the needs of simulation in the health systems area in particular.

6 CONCLUSION AND FUTURE WORK

Our observations on the literature have led us to consider the relationship between the various components of a policy assessment regime. We observe a complementarity between broad policy assessment methods which have to take into account multiple, often ill-defined views and more focused and precise system representations through use of simulations, a complementarity which is, perhaps necessarily, an uneasy one. The simulation seeks precision in requirement, the broad policy method seeks engagement, breadth of representation and generality, but in order to support the process of sound policy identification and hence assessment, these two must work together. We observe a lack of deployment of wider soft OR methods in simulation requirement capture leading potentially to simulation designs which are sub-optimal with respect to the inclusion of the widest possible sources of system knowledge and benefit valuations of the system outputs. While soft system methods are seen as uniquely powerful in eliciting multiple viewpoints from stakeholders and system owners, we encourage the deployment of those system representation methods such as QSD which can accommodate multiple viewpoints but in such as way as to communicate directly with the simulation requirements process. Work is in hand to establish the practicality of using the toolset of QSD (Powell and Coyle 2005) not only in the area of health system representation and assessment, but in the associated fields of (safety and mission) *critical human activity systems* (CHASs) such as disaster and crisis management and high risk environments.

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