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Decision Support

A toolkit of designs for mixing Discrete Event Simulation and System Dynamics

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ABSTRACT

In recent years there has been significant interest in multimethodology and the mixing of OR/MS methods, including Discrete Event Simulation (DES) with System Dynamics (SD). Several examples of mixing DES and SD are described in the literature but there is no overarching framework which characterises the spectrum of options available to modellers. This paper draws on a sample of published case studies, in conjunction with the theoretical literature on mixing methods, to propose a toolkit of designs for mixing DES and SD which can be implemented as a set of questions which a modeller should ask in order to guide the choice of design and inform the associated project methodology. The impetus for this work was the perceived need to transfer insight from reported practice in order to formalise how the two methods can be and have been mixed.

1. Introduction

Multimethodology and the mixing of OR/MS methods continue to be of interest to the OR/MS community (Howick & Ackermann, 2011), with increasing attention to the application of a mix of simulation methods (Pidd, 2012). This paper focuses on mixing DES and SD, a combination which is increasingly often reported in the literature and several position papers which support this mix exist (Brailsford, Desai, & Viana, 2010; Lane, 2000; Pidd, 2012). However, how DES and SD can be and have been mixed is not well defined. Software tools are available offering the functionality of both methods within a single environment, [1] but there are multiple ways of mixing the methods and the most appropriate will depend on the context. Therefore there remains a need to collate and expand existing frameworks to develop *"a conceptual philosophy and practical methodology for combining SD and DES in a real context"* (Viana, Brailsford, Harindra, & Harper, 2014, p. 197) enabling modellers to better understand how DES and SD can be mixed and thereby inform practice. This paper reviews the literature relating to mixing DES and SD in theory and practice in order to propose a toolkit of mixed methods designs for mixing DES and SD and to inform the associated project methodology. The research described was conducted to inform, and was reflected upon throughout, an action research project in collaboration with the Beatson Oncology Centre, Glasgow (detailed in Morgan, Belton, & Howick, in press).

Although all modelling projects are unique, reviewing the literature to find points of commonality enables a researcher to make connections between ideas, theories and experiences (Hart 1998) and ultimately to pass on understanding. General reviews and classifications of mixing methods within OR/MS modelling exist, but papers with a DES and SD focus are context specific. There is currently not an overarching framework that covers: the spectrum of options available to a modeller (taking a broader OR/MS mixed methods approach), the technical details which need to be considered when mixing these methods, and the importance of project context. Such a generic framework should provide insight into the philosophical, methodological and technical considerations when using each method within a mixed method design. The development of appropriate software might also alleviate some of the barriers to mixing methods, but this is outside the scope of this paper. However, whilst some multi-method software provides an environment within which to build a conceptualised mixed model, it is important to be aware that if a modeller does not have clear paradigm and conceptual guidance this may lead to an inappropriate or over-complex model.

In addition to the availability of software, there is a need to support modellers interested in mixing OR/MS methods by asking what method should be used when (Flood & Jackson, 1991). This

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[1] Examples include: Aivika (hackage.haskell.org/package/aivika-0.1), AnyLogic (www.xjtek.com/AnyLogic), GoldSim (www.goldsim.com).

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paper takes frameworks from the wider OR/MS mixed methods literature and seeks to adapt them to the simulation context, drawing on a number of published projects which mix DES and SD, in order to present a toolkit of designs that have been shown to work in practice and have overcome concerns of paradigm compatibility.

The next section presents the background to this research, comparing DES and SD to highlight the differences, commonality and complementarity of the methods and summarising interest in mixing OR/MS methods. Section 3 describes the preliminary mixed methods designs collated through analysis of the mixed methods literature. Section 4 examines a number of mixed DES and SD projects selected from the literature and considers their implications for the mixed method designs described in Section 3. The paper concludes by proposing a toolkit of mixed method designs and discussion of the implications for and on methodology selection in practice.

2. Background

This paper adopts a similar view to Howick and Ackerman (2011) in that the aim is to examine the literature for *"all forms of mixing methods"* (p. 504), and considers the spectrum of how DES and SD can be and have been mixed. The term mixing methods is used in this paper to describe the combined use of more than one technique, tool, method, methodology or paradigm. The term method will be utilised to describe both DES and SD; reflecting a general descriptor of OR/MS methods, tools and techniques. Methodology, in this paper, will refer to the overall structure of the intervention which may consist of a mixed methods design. This approach reflects Mingers and Brocklesby's (1997) definition that a methodology describes 'what type of activities should be undertaken' and the method is the 'how'. Paradigm will refer to the theoretical perspective, the philosophical context grounding the method logic (Crotty, 1998).

2.1. Comparison of DES and SD

2.1.1. System Dynamics

SD is a form of continuous simulation modelling that may be characterised by its ability to represent feedback in systems (Forrester, 1958). SD models the average flow of the system rather than individual events, explicitly representing delays and feedback experienced within a system to discover underlying principles and behaviour over time. The efficacy of SD is based on its ability to capture the whole system rather than focusing on short term goals and single measures of performance, which can lead to inappropriate conclusions (Taylor & Dangerfield, 2005). SD models are, in general, a macroscopic view of a system, which may be used to explore how the system structure impacts the system behaviour.

2.1.2. Discrete Event Simulation

DES is a method in which the dynamics of the system are triggered by events, allowing users to model the individual events experienced within a system. DES enables the user to explore progression through a system (Pidd, 2004) and is often used to represent systems at an operational level, where the individual interactions and the variation of experience of system entities over time is important. The variability inherent in everyday life can be captured and the multiplicative effect of stochastic elements can be observed, but DES does not explicitly seek to model feedback.

2.1.3. Comparing methods

DES is one of the most popular OR/MS modelling methods and has been used with other OR/MS methods such as statistical analysis, data mining, problem structuring, process flow mapping, optimisation and multi criteria decision analysis (Robinson, 2005).

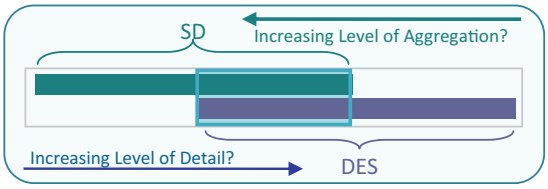

Fig. 1. The possible continuum of DES and SD.

Lane (1999) assures that SD is not restricted to one paradigm and may be mixed with other methods as Forrester's ideas operate at the 'method' level. Enabling modellers to "*see enough of the 'other' discipline to sense where future collaboration might be beneficial*" (Morecroft & Robinson, 2006, p. 11) may encourage modellers to become less anchored to their method of choice. Comparing the methods supports mixing by allowing modellers to view characteristics of both methods side-by-side, revealing the overlap and gaps.

There are numerous studies that consider both methods (for example: Chahal & Eldabi, 2008a,b; Tako & Robinson, 2010), with the focus recently on providing a more balanced and empirical comparison, which seeks to consider how mixing the methods could "*yield complementary* insights" (Morecroft & Robinson, 2006, p. 11). Pidd (2004) notes three perspectives which need to be coherent in order to select appropriate methods: the methodology, the problem and the system. Table 1 draws together comparative studies of DES and SD using these three perspectives. The methods are clearly distinguished by some characteristics (such as the extent to which stochasticity is modelled) and are more closely aligned on others (such as the need for good data). Other characteristics may overlap depending on how they are implemented (illustrated in Fig. 1 for the characteristic "level of detail incorporated in a model").

Despite the differences, Sweetser (1999, p. 8) noted that *"many problems could be modelled by either approach and produce results that would look very similar"*. However, method choice influences what is included and excluded from the model, which in turn affects the results (Davies, Roderick, & Raftery, 2003). When learning a method, a modeller learns to view a system in a certain way and this impacts their choice of method, hence proponents of either method may naturally tend towards its use but it can be informative to take a *"step back and assess which toolkit should be used"* (Chick, 2006, p. 22).

2.2. Mixing OR/MS methods

Real-world problem situations are often highly complex and it is possible to use different methods to focus on different aspects of a situation. Jackson and Keys (1984) suggest that the OR/MS community is motivated to mix methods by a desire to improve modelling capabilities and increase the effectiveness of modelling projects. All methods have their strengths, weaknesses, benefits and limitations; mixing methods offers the potential to overcome some of the shortfalls, providing an additional methodology to cope with wicked problems and systems.

In their 2002 survey Munro and Mingers found that mixing OR/MS methods happened because each method was *required*, and that methods were mixed in an adhoc/emergent manner. More recently Howick and Ackermann's (2011) review of papers, which describes mixing OR/MS methods in practice, revealed a number of reasons for mixing including: to deal with a complex problem system, to support stages of a project, to obtain specific benefits from specific methods and to overcome method shortfalls.

There are also some concerns relating to mixed methods. Concerns of paradigm incommensurability, which are discussed in