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Towards fully-facilitated DES modelling: A successful project

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Abstract

The literature suggests that increasing stakeholder engagement in modelling has a positive impact on healthcare improvement projects using discrete-event simulation (DES). This suggests analysts should strive for the 'fully-facilitated' mode of simulation, meaning conducting the whole simulation project together with stakeholders. This paper investigates whether this might be possible in practice. This work arose from a research project with an Italian hospital. The paper describes a simulation project that succeeds in being fully-facilitated through all stages as far as the implementation stage, through combining Business Process Model and Notation (BPMN) and DES. We believe it is the first time that a fully-facilitated DES project in healthcare has been described.

Keywords: OR in health services, Simulation, Facilitated modelling, BPMN.

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1. Introduction

Simulation has a long history in healthcare appearing over half a century ago and interest in it has been increasing since the 1990s due to the increased availability of computer technology (Pitt, Monks, Crowe, & Vasilakis, 2015; Robinson, Radnor, Burgess, & Worthington, 2012). Objectives in applying simulation in health projects include risk reduction in changes to processes, cost and time reduction, and better understanding of healthcare pathways among their stakeholders. In particular, the literature shows a growing interest in using discrete-event simulation (DES) as a tool for facilitated modelling (Robinson, Worthington, Burgess, & Radnor, 2014). DES generally requires complex models and detailed data, aiming to provide an objective analysis leading to optimal (or at least good) solutions. The goal should be to build a model that is 'requisite', meaning that the form and content of the model are sufficient to solve a particular problem (Phillips, 1984). This is the classical 'anathema' to 'facilitated' modelling, where facilitated modelling in DES means involving stakeholders during all the phases of a simulation study (Brailsford, Bolt, Connell, Klein, & Patel, 2009; Robinson et al., 2014; Tako & Kotiadis, 2015). Indeed, implementation of DES in healthcare is still problematic because healthcare systems have complex behaviour and involves many stakeholders with a plurality of opinions and objectives (Franco & Montibeller, 2010; Pitt et al., 2015; Proudlove, Black, & Fletcher, 2007; Robinson et al., 2012; Tako & Kotiadis, 2015). Thus, it is difficult to both engage stakeholders during a simulation study and manage the conflicting interests of multiple stakeholders (Brailsford, 2005; Jahangirian, Taylor, Eatock, Stergioulas, & Taylor, 2015; Taylor, Eldabi, Riley, Paul, & Pidd, 2009). This apparent lack of success of implementing simulation studies in healthcare has prompted authors to reflect on the specific barriers in healthcare, particularly managing to obtain stakeholder engagement and maintain their involvement (Brailsford, 2005; Brailsford et al., 2009; Jahangirian et al., 2015; Taylor et al., 2009). In addition, Robinson et al. (2014) emphasise that, in healthcare, to succeed, a simulation study should engage stakeholders throughout its lifecycle. To the best of our knowledge, there are only three studies that have proposed approaches to achieve facilitated DES modelling in healthcare, namely the CM

framework (Kotiadis, Tako, & Vasilakis, 2014), PartiSim (Tako & Kotiadis, 2015), and SimLean (Robinson et al., 2012; Robinson et al., 2014), but none of these studies can be described as a 'fully-facilitated' DES modelling because there is not involvement of the stakeholders during *all* the simulation stages (in particular the 'model coding' stage).

This paper focuses on striving for the fully-facilitated mode of simulation to maintain stakeholder engagement in healthcare improvement projects using DES. This work arose from a research project with an anonymous Italian hospital. We investigate whether it might be possible in practice to obtain and maintain stakeholder engagement through using Business Process Model and Notation (BPMN) with DES. BPMN is a standard notation for process modelling which the literature suggests may overcome many of the known barriers to stakeholder engagement.

Thus, the research question was:

> *Can BPMN help overcome barriers to stakeholder involvement in a simulation study in healthcare?*

We describe a DES modelling project that succeeds in being fully-facilitated in a particular context through using BPMN for the design of conceptual models and automatic generation of DES structure. We believe it is the first time that a fully-facilitated DES study in healthcare has been described.

The paper is structured as follows. The following section briefly explores the relevant literature to facilitated DES modelling and stakeholder engagement in healthcare, highlighting the main barriers to the implementation of simulation studies. It also considers evidence from the literature that suggests that using BPMN computer-based process mapping tool may be useful in overcoming these barriers. The third and the fourth sections explain the research methodology and how our approach was tested in the hospital. A discussion follows with reflections on the usefulness of the approach. This section also points out the practical and methodological implications as well as an outline of future research work.

2. Literature

There is much evidence in the literature of barriers to the success of simulation projects in healthcare stakeholder engagement, in particular poor stakeholder engagement has a

considerable impact (Brailsford et al., 2009; Harper & Pitt, 2004; Jahangirian et al., 2015). The main response is to emphasise the importance of and strive towards a facilitated modelling approach in which the greater engagement of stakeholders can lead to a better quality model and can promote debate and understanding of the possible changes to processes (Franco & Montibeller, 2010). Three recent projects have proposed a facilitated DES modelling approach in healthcare, namely the Conceptual Modelling (CM) framework (Kotiadis et al., 2014), PartiSim (Tako & Kotiadis, 2015), and SimLean (Robinson et al., 2012; Robinson et al., 2014). None of these studies can be described as a fully-facilitated DES modelling because there was no involvement of the stakeholder during the 'model coding' stage. This model coding stage is where the conceptual model (i.e., a description of the model) is developed into a computer simulation using a programming language, spreadsheet or simulation software (Robinson, 2014). Robinson et al. (2014) point out that unless the challenge of model coding with client involvement can be met, then fully-facilitated DES modelling is not and never will be possible. They suggest that a further step in better involving the stakeholder during model coding is to use a technical solution, for example by generating the process map in electronic form.

BPMN is a standard for process modelling in electronic form that is supported by many large vendors (such as IBM, Oracle, SAP, etc.) (Onggo, 2012) so is widely available, including in free software tools. Some DES tool vendors enable models to be built or imported in BPMN format (e.g. *Simul8* and the *L-SIM* simulation server), for automatic generation of DES model structure (Bisogno, Calabrese, Gastaldi, & Levialdi Ghiron, 2016; Onggo & Karpat, 2011; Recker, 2010). The automatic generation of a DES model from BPMN is made possible by another standard called BPSim. BPMN and are integrated in some BPM software, such as *Bizagi* (Bisogno et al., 2016).

BPMN also has features to support building complex processes showing the hierarchy between activities and sub-activities (OMG, 2011). It is an appealing tool for use in conceptual modelling (Bisogno et al., 2016; Onggo & Karpat, 2011) and has the advantage of supporting the implementation of a conceptual model by directly generating software code (Recker, 2010). BPMN has been obtaining high levels of attention in business practice (Recker, 2010) and has also been shown to be understandable by healthcare professional and to have rich semantics for modelling

medical processes (Yaoa & Kumar, 2013). It is also accessible since the use of BPMN does not require any licence fee; many software tools support BPMN and some of them are free (Onggo & Karpat, 2011; Recker, 2010).

3. Research methodology

The features of BPMN identified in the literature leads us to hypothesise that BPMN might provide a way to overcome some of the barriers to stakeholder engagement identified, in particular the issue of model coding.

We were able to test this hypothesis through a research project with an Italian hospital. The simulation project cycle applied here (Figure 1) is an adaptation of that suggested by Robinson (2014). The approach we propose we have named ‘FaRe’: the Facilitated and Requisite modelling approach.

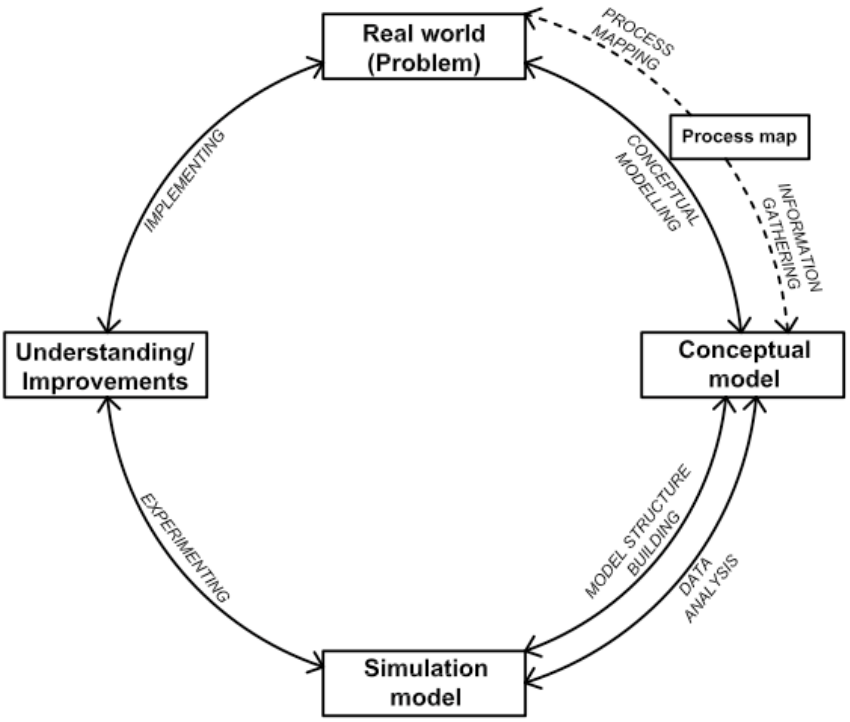

Figure 1: The FaRe Simulation Cycle

The key activities of the simulation cycle are: conceptual modelling, building the simulation model (‘model coding’, involving model structure building and data analysis) experimentation and implementation. In a fully-facilitated mode, the

stakeholders should be involved during *all* the steps of a cycle. A simulation study starts after the recognition that an appropriate problem exists in the real world. To build the conceptual model, researchers and stakeholders need to understand the problem situation and identify inputs and outputs of the model. In this phase, it is important to identify the correct KPIs and the level of detail necessary and to find out what useful information is available about the process to be analysed (i.e. establishing what is required for *requisite* modelling). Conceptual modelling can be conducted as two separate activities: i) building a 'basic' process map, using for example paper, post-it notes or flow-charts, and ii) gathering information that is useful to build the conceptual model. In the FaRe approach, the conceptual model is built using the BPMN standard from which a DES model can be directly generated without any coding. This can be done using BPSim, an industry-standard that defines information needed to enable the simulation of a conceptual model written in BPMN. A number of tools, such as *Bizagi*, provide a seamless integration between BPMN and DES so that a modeller can draw a conceptual model using BPMN, define the required parameters and simulate the model in an integrated model development environment. Other tools, such as *Simul8*, provide a facility to import a conceptual model written in BPMN model and require a modeller to specify the required parameters and simulate the model using their proprietary software. We consider that the term 'model coding' as adopted by previous authors is often unhelpful in describing the activity in which a computer model is generated automatically (or semi-automatically) from a conceptual model, especially when a technical solution for the design of the conceptual model (e.g. the BPMN and BPSim standards) is considered. The conceptual model suggests which data are required for simulation modelling requisite for the task. If detailed data are required and available, then data analysis subsequently adds further information to the model. Once the simulation model is developed and data are analysed, different scenarios are run and validated in order to explore potential improvements that might be implemented in the real world. Hence, this problem solving approach aims to achieve facilitated and requisite simulation modelling (i.e. FaRe) through the integration of BPMN and DES.

4. Testing the FaRe approach

Given that there are several features of BPMN that lead us to hypothesise that BPMN might provide a way to overcome recognised barriers to stakeholder engagement, we set out to investigated our research question: whether BPMN might achieve this, by testing our proposed fully-facilitated and requisite DES modelling approach (i.e. FaRe).

The FaRe approach 'test' was conducted in an anonymous hospital in the north of Italy. The process analysed considers the patient flow during the pre-operative visit in the orthopaedic outpatient clinic (OC) of the hospital. The process begins when patients arrive at the OC to be assessed before the orthopaedic surgical operation is scheduled.

Prior to our engagement with the hospital, staff had done some limited process mapping using *PowerPoint* and *Excel*. They were interested in taking this further, which gave us the opportunity to investigate a fully-facilitated modelling approach using tools we were familiar with: BPMN combined with BPSim using the free version of *Bizagi*.

We organised several meetings over a week in September 2013 with surgeons and nursing staff. The stakeholders wanted to investigate the trade-off between staff utilisation rates and patient waiting times (their KPIs), and how the appointment scheduling (arrival rate) impacts on this, in order to consider adjusting the booking system. We discussed how to map patient flows in the orthopaedic outpatient clinic and how they might be improved. We briefly showed the main features of BPMN, how to use it to map processes and some previous applications of this standard seeking to understand the dynamics of healthcare processes. The clinicians described the process and we observed it in action. We then built the conceptual model of the pre-operative patient flow directly on the computer using *Bizagi* software with the clinical staff present. Since there was little available data for the process, we populated the simulation model with process time and patient inter-arrival time distributions and parameters based on suggestions from the stakeholders. In the simulation model, no warm-up period was required since the outpatient clinic starts and ends empty every day. The scenario duration was set to the length a typical workday shift (8 hours), during which the resources available in the orthopaedic OC were not shared among different patient flows of other wards. As BPMN and BPSim are both integrated in the *Bizagi* software, we were able to seamlessly move into simulation mode with the

stakeholders present and conducted experiments using the simulation model with them. Figure 2 shows the simulation screen in *Bizagi*.

The nature of the system modelled is relatively simple in modelling terms, with dedicated resources, empty starts and straightforward flow. In addition, it was considered sufficient by the stakeholders to establish the direction of change that would be likely to achieve their desired improvements. They were not looking for a model that could produce 'hard' predictive results. Hence, the simulation model was requisite to address the issues.

The stakeholders (i.e. clinical staff) interacted well with the researchers, who acted as change agents over the entire simulation lifecycle. Thus, it was possible to achieve a fully-facilitated mode of modelling, which we believe to be the first fully-facilitated and requisite DES modelling approach to be described in healthcare. The main achievement here is that we have managed to build the model with the stakeholders using BPMN and BPSim standards. Unfortunately due to major geological issues with the site, the hospital has been merged with another hospital and all inpatient facilities at the original site were closed. Hence, it is not possible to implement the recommendations at the original site.

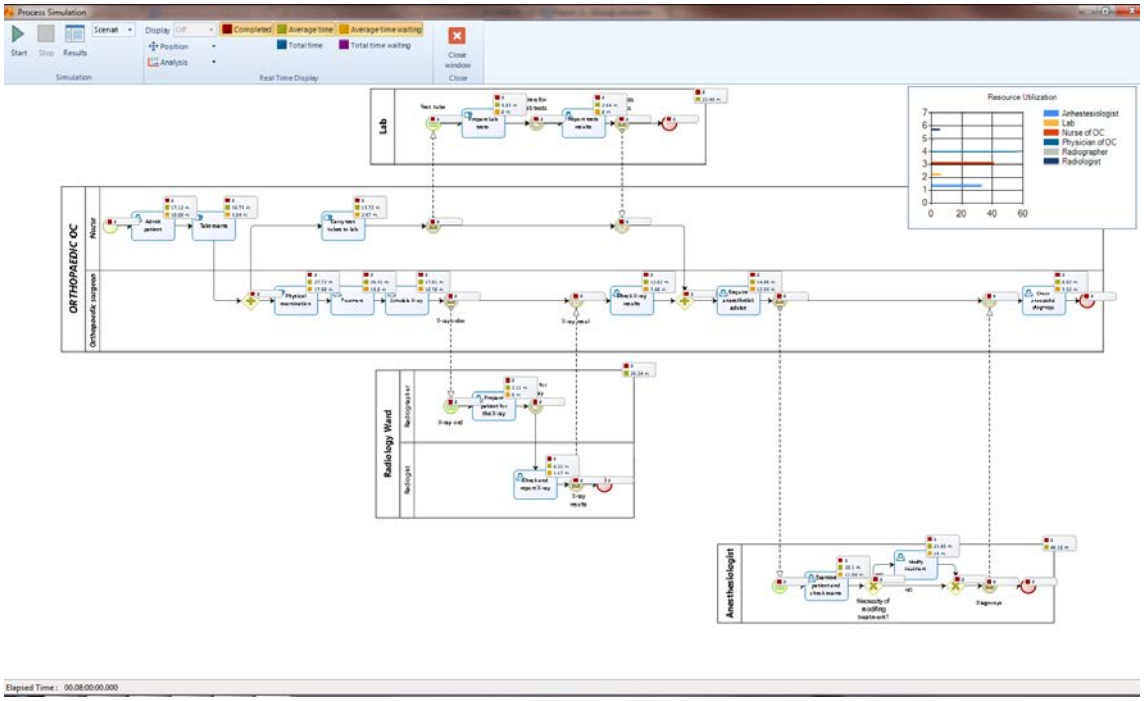

Figure 2: Simulation model example: pre-operative patient flow (Project A).

5. Discussion

In this section, we provide our observations of testing a facilitative and requisite DES modelling approach (the FaRe approach). We also outline some future research directions in order to extend this approach.

The literature contains very little in the way of convincing descriptions of implementation of changes tested by simulation projects in healthcare (as noted by, for example, Pitt et al. (2015)). As noted earlier, a response has been a series of papers considering particular barriers in healthcare (Brailsford, 2005; Robinson et al., 2014) and, in particular, what might be done about stakeholder engagement (Kotiadis et al., 2014; Robinson et al., 2012; Tako & Kotiadis, 2015), which in turn has led to a renewed emphasis on striving for fully-facilitated simulation modelling (Franco & Montibeller, 2010; Jahangirian et al., 2015).

Can BPMN help overcome barriers to stakeholder involvement in a simulation study in healthcare?

We conducted a first test of the FaRe approach in an Italian hospital and succeeded in achieving a fully-facilitated and requisite mode of modelling in healthcare through using integrated BPMN and BPSim DES tools to overcome barriers to stakeholder engagement. We believe it is the first example in the literature of a fully-facilitated and requisite DES project, at least as far as implementation, in healthcare. This project was a relatively straightforward modelling task involving a simple pathway, empty-start system and a simple queuing system. The simulation model was populated by estimated data provided by stakeholders because there was no available data from the hospital for the process analysed. This lack of data availability is not an unusual situation in healthcare (Santibáñez, Chow, French, Puterman, & Tyldesley, 2009).

Stakeholders were engaged and committed to pursuing implementation of the changes tested through the simulation project. However, due to geological risk at the site, a higher-level decision to close all inpatient services was imposed. Thus, failure to implement was not a stakeholder issue or engagement barrier, but the project being ‘swept away’ by a very major reorganisation. Despite lack of implementation, we have demonstrated that the gap identified in Robinson et al. (2014) can be closed in some circumstances.

The use of the technical solution (i.e. the combination of the BPMN standard and the BPSim DES tool) permitted us to meet the challenge of building the simulation model with stakeholders involved over the entire simulation-study cycle (Robinson et al., 2014), overcoming all the barriers identified in the literature. In particular, BPMN helps to overcome the barriers of complex models proposed by academics and the communication gap between simulation and stakeholder groups by building a model with stakeholders that they can understand, starting with a simple visual process model/diagram. We documented some comments from the stakeholders at the hospital about these BPMN features:

> "*The BPMN model is easily readable and more understandable than a flowchart or an Excel spreadsheet model. In comparison with an Excel spreadsheet model, the BPMN diagram shows the process flow and connections between the activities. Also, in comparison with a flowchart, the BPMN model shows the person responsible for each activity.*"

As suggested in the literature, BPMN directly integrated with the BPSim DES tool can easily overcome the problem of the simulation modelling as a time-consuming activity. Indeed, the 'model coding' is very straightforward, the model structure building is seamless and the data entry is in the same environment.

Overcoming the complexity of healthcare problems can be possible by using BPMN's facility to construct a hierarchy of processes with sub-processes inside them, by capturing the resource responsibilities through pools and lanes and by separately catching data flow, as suggested by for example Barforooshi, Moghadam, and Nasiri (2010); OMG (2011); (Onggo & Karpat, 2011). Other interesting comments from the stakeholders included:

> *"The simulation tool (i.e. BPSim in* Bizagi*) also helps the clinical staff to understand the rate of their utilisation in the process. Indeed, it can be used by managers, but also as doctors and nurses we find it useful to see our utilisation."*

These last comments also indicate the positive feelings of the stakeholders about the simulation tool as part of an integrated environment that appears user-friendly. In addition, building the conceptual model with the BPMN standard that is directly integrated into a DES tool makes the conceptual model stronger and helps to overcome

barriers noted in the literature concerning difficulties with understanding and working with simulation, as suggested for example by Recker (2010).

Other barriers highlighted in the literature (such as unacceptable results for stakeholder, failure to meet project objectives, stakeholder engagement at all stages of any project and poor awareness of simulation) can be overcome considering that, from the process map, the BPMN conceptual model built with the stakeholder is seamless and integrated with the simulation tool. It enables the stakeholders to be present throughout to validate the model. Also on the subject of and the integration of BPSim with BPMN, the stakeholders commented:

> *"… That simulation tool (i.e.* Bizagi*) helps to visually understand the process flow, even for people who do not have a technical background and it is generally easy to use."*

Many software tools support BPMN and some of them are free (Onggo & Karpat, 2011; Recker, 2010), including *Bizagi*, enabling the barrier of high costs to be overcome. The project in the Italian hospital used judgemental data and modelled a simple situation. We succeeded in applying a fully-facilitated and requisite modelling approach by combining BPMN and an integrated DES.

There are, of course, limitations to the research reported here. We regret to be adding to the list of non-implemented simulation projects, a record that does not appear to be improving: large surveys suggested 92% non-implementation several decades ago (Wilson, 1981) and around 94% more recently (Brailsford & Vissers, 2011).

We were fortunate to be working in an environment where the general barriers to engagement reported in the literature (section 2) were very low. Beyond that, the degree of engagement in the project led us to believe that the barriers to implementation in healthcare projects previously reported had been overcome. That the key contribution was BPMN as a way-in to conceptual modelling and a gateway to DES is apparent from its capabilities and the reactions of the stakeholders.

Further work is to consider how BPMN, and its link to DES tools, may be enhanced to extend the range of situations in which this approach could be applied.

6. Conclusions

The paper describes a DES modelling project that succeeded in being fully-facilitated and requisite in a healthcare modelling project. This research demonstrates the potential of BPMN for overcoming some barriers to better involving stakeholders in a simulation study in the healthcare context. We combine BPMN and DES to propose a fully-facilitated DES modelling cycle that is also requisite to solve healthcare problems. We believe it is the first time that such a fully-facilitated DES has been described. From a practical point of view, BPMN is a standard that is readily understandable by non-analysts and so can help to bridge the gaps between different groups involved, particularly the frontline staff vs. QI/SI staff and OR analysts.

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