Proceedings of the 2008 Winter Simulation Conference
S. J. Mason, R. R. Hill, L. Mönch, O. Rose, T. Jefferson, J. W. Fowler eds.

APPLICABILITY OF HYBRID SIMULATION TO DIFFERENT MODES OF GOVERNANCE IN UK HEALTHCARE

Kirandeep Chahal

School of Information Systems,
Computing and Mathematics
Brunel University
Uxbridge UB8 3PH, U.K.

Tillal Eldabi

Brunel Business School
Brunel University
Uxbridge UB8 3PH, U.K.

ABSTRACT

Healthcare organizations exhibit both detailed and dynamic complexity. Effective and sustainable decision-making in healthcare requires tools that can comprehend this complexity. Discrete event simulation (DES) due to its ability to capture detail complexity is widely used for operational decision making. However at the strategic level, System Dynamics (SD) with its focus on a holistic perspective and its ability to comprehend dynamic complexity has advantages over DES. Appreciating the complexity of healthcare, the authors have proposed the use of hybrid simulation in healthcare. As argued previously, effective decision making require tools which are capable of comprehending both detail and dynamic interactions of healthcare. The interactions in the organizations are governed by the governance design. In appreciation of that argument the authors have described the applicability of a hybrid approach to various modes of governance in UK healthcare.

1 INTRODUCTION

Changing demographic trends, increased customer expectation and reactive government policies are all fuelling the crisis in the NHS. Healthcare providers are experiencing enormous pressure from public and government to improve provision of healthcare. In response to these pressures healthcare is undergoing a radical transformation. Due to the large number and diversity of the constituting organizations, complexity of healthcare system is overwhelming and beyond the comprehending capacity of the human mind. As healthcare is highly intolerant to failures, healthcare providers require tools to foresee the consequences of their decisions. The need to evaluate these decisions prior to implementation is well recognized (Sobolev, 2005; Walshe and Rundall, 2001; Watt et al 2005). One way to explore the different consequences of alternative decision scenarios effectively is simulation and modeling. Although there is considerable literature reported on the use of simulation modeling in healthcare, its impact on healthcare decision making has not been deployed to its full potential (Lowery et al, 1994; Lowery, 1996; lowery, 1998; Proudlove et al 2007, Brailsford, 2006). Eldabi et al (2007) have argued that both simulation and healthcare can benefit from each other symbiotically.

The use of simulation approaches for healthcare issues has received a great deal of attention recently. Eldabi et al (2007) have described a dramatic increase in healthcare studies since 2000. Discrete Event Simulation (DES) and System Dynamics (SD) are two approaches to simulation modeling which are being widely used in healthcare. Both DES and SD model the behavior of the system over the time. DES as a methodology is based on the philosophy that behavior of the system over time is cause of its endogenous and exogenous variation (Morecroft and Robinson 2006). SD on the other hand is based on the philosophy that the structure of the system is responsible for its behavior over the time (Morecroft and Robinson 2006).

Where as both SD and DES offer advantages in modeling certain aspects of a system, both have their limitations. The authors argue that integrated healthcare poses challenges to the use of SD and DES in isolation. In the appreciation of healthcare as an integrated system, the authors have proposed the use of hybrid simulation for effective decision making. Hybrid simulation is the deployment of SD and DES in an integrative way, where both paradigms symbiotically enhance each others capabilities and mitigate limitations by sharing information. The authors argue that this approach will allow decision makers to evaluate their decisions from both microscopic (capturing detail up to individual level) as well as macroscopic (holistic system wide interactions) views. The authors have further enhanced their contribution by providing a description of applicability and effectiveness of this approach to various modes of Governance in UK healthcare. The structure of the paper is as follows. The following section provides an overview of DES, SD, their use and limitations in context of healthcare. Section 3 provides description of hybrid simulation formats. Section 4 describes different modes of governance in UK healthcare and applicability of hybrid simulation to different modes. Finally section five concludes the paper.

2 SIMULATION MODELING IN HEALTHCARE

Healthcare systems are complex and adaptive systems with multiple stakeholders, where numerous strategic, tactical and operational decisions are made on routine bases. To achieve viable decisions, it is important for all the stakeholders to understand the complexity and have a shared vision of the process. Modeling in general is one of the most widely used tools to support decision making. There are many modeling techniques used in healthcare modeling, such as, decision trees, Markov modeling, simulation modeling and other statistical methods. Where as Decision trees and Markov modeling deal only with aggregate solutions, simulation modeling deals with individual as well as aggregated entities. Use of simulation modeling in healthcare systems around the world is gaining momentum. Two categories of simulation that have gained prominence in the past decade are DES and SD. The following subsections provide a brief discussion about use and limitations of DES and SD modeling in healthcare systems.

2.1 Use of DES in Healthcare

DES modeling is a technique well established in disciplines such as manufacturing and scheduling. Some key texts include Banks (2001) and Law & Kelton (2000). DES models attempt to imitate the observed behavior of the problem, typically by using stochastic distributions to generate events and quantities typical for the system. Problems are typically conceptualized as networks of queues and servers. Consider the example of a clinic with regular patient entry. Patients wait for registration, after registration, they wait for treatment in the queue until they are given treatment and after the treatment, they leave the clinic. The registration requires a registration nurse and the treatment requires a doctor and a nurse in order to go ahead. A simple DES model of this problem may be described by Fig.1

DES describes the flow of patients through the treatment system (Davies and Davies, 1994; Karnon and Brown 1998, Caro, 2005). Fone et al (2003) conducted a review of DES in healthcare and reported that DES models had been used to evaluate many healthcare areas, including hospital scheduling and organization, communicable diseases and screening. Jun et al (1999) conducted a survey on application of DES to understand the operations in healthcare. They have identified that most of the research has been conducted in the area of patient flow and resource allocation. Their survey has also revealed that in most of the scenarios DES has been applied to detailed microscopic analysis of individual units with in the multi-facility integrated clinics. They reported lack of literature on application of DES to model the holistic view and argued that this could be due to the increase in complexity associated with modeling integrated systems and due to increase in required resources in terms of time and cost. Lowry (1992, 1993) in his study of hospital critical care has also highlighted the fact that most DES models do not fully consider the inter-relation ship between different hospital units. Jacobson et al (2006) have provided a comprehensive review of the use and limitations of DES in the context of healthcare.

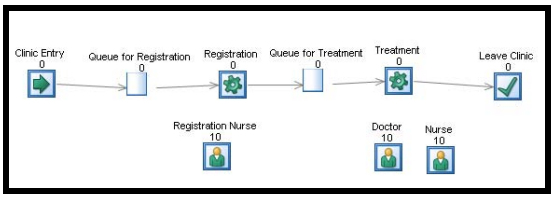

Figure 1: Simple DES model of a healthcare problem

Although DES has become increasingly popular in recent years, and is an ideal tool for micro level analysis, they are not well suited to represent the macroscopic view of system taking into account the complex effects produced by interacting processes. This is where SD has advantages over DES. The following section will provide an overview of SD and its use.

2.2 Use of SD in Healthcare

SD is based on the philosophy that behavior of the system over the time is determined by its structure. SD is an analytical technique developed by Jay Forrester (1961, 1968) in his work on industrial dynamics. SD models attempt to reproduce the causal structure of the problem, identifying components and feedback loops that are the cause of the dynamic behavior observed in the system. Models attempt to focus on the systemic properties of the problem caused by the interaction of flows, interdependencies and delays. They may also include "soft variables", qualities that are not measured directly yet are proposed to influence behavior.

There are two common forms of notation, Causal Loop Diagrams (CLDs), which capture the conceptual relationships in the problem, and Stock-Flow diagrams which describe the structure of the system in more detail. Only Stock-Flow diagrams are implemented as simulations. Both are described in detail by Sterman (2000).Consider the simple example of a hospital operating on a fixed level of external funding. Patients may chose the hospital due to its reputation based on a combination of the treatment outcomes and waiting times reported. Treatment outcomes are influenced by the level of the population. Stock and flow models of this problem may be described by fig2.

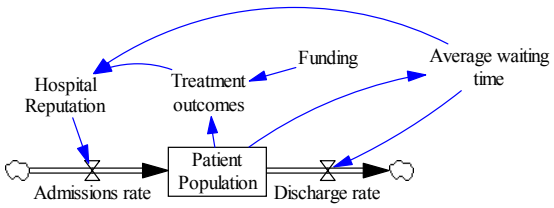

Figure 2: Simple SD model of a healthcare problem

The SD model is intended to provide an impression of the dynamic trends resulting from the system structure rather than reproduce observed behavior exactly.

As compared to DES, there have been relatively few applications of SD in healthcare. Dangerfield (1999) presented a survey of SD applications in European healthcare and reported that most of the SD models were either used for persuasion purposes or for providing a framework for evaluation of tactical studies. SD models are more appropriate for studying the interrelationship between healthcare components. Lane et al's (2000) model of A& E clearly shows the connection of A& E with other parts of the healthcare system. SD models unlike DES models do not produce detailed results at the individual level. Their purpose is to generate insight into the system rather providing accurate predictions. The next section will present the limitation of these modelling approaches.

2.3 Limitations of SD and DES in healthcare context

Healthcare systems are complex adaptive systems (Begun et al. 2003). Healthcare complexity comprises of both details as well dynamic complexity. Although DES models detail complexity, it is not well suited to model dynamic complexity. These models lack the global vision, which can represent the dynamic interaction between system components. Most of the DES studies have been confined to single departments or sections. Since many issues and processes in healthcare cross all departments and sectors, decision making for a single department results in poor balance of resources across the healthcare system as whole. The few attempts to make DES models of whole systems has been prone to criticism either for being too simple to represent the real system or too complicated and rigid to aid understanding and flexibility.

Due to increasing appreciation of healthcare as an integrated system, another simulation approach "System Dynamics" which is able to model complex, large, integrated systems, is gaining a lot of popularity. SD is appropriate for representing the dynamic complexity. Instead of individual detail, SD models focus on aggregates and model interactions between system's components from a global perspective. In healthcare both interactions between various components as well as detailed individual tracking are equally important. The SD model can't differentiate between individuals on the basis of their attributes. This differentiation is crucial in healthcare systems as many decisions are based on patient attributes.

From the above discussion it is quite obvious that where both SD and DES have much to offer in comprehending the complexity of healthcare, both have limitations as well. However both their capabilities and limitations appear to complement each other. The author believes that an integrative hybrid (SD+DES) approach which deploys the capabilities and mitigates the limitations of both will provide the healthcare decision maker with an invaluable tool to visualize the system from both holistic macroscopic perspective as well as detailed microscopic perspective.

3 PROPOSED HYBRID SIMULATION IN HEALTHCARE

The authors argue that in a system like healthcare where both detailed and dynamic complexities are critical, decision making require tools for comprehending these complexities. Although there has been extensive use of SD and DES in healthcare, the authors have not been able to find any reported studies which deploy both methods in an integrated way. This could be due to the fact that both communities tend to have little appreciation for each other (Morecroft & Robinson, 2006; Lane, 2000; Brailsford and Hilton, 2002). However there is current awareness and emphasis on combining these two methods (Eldabi et al 2007 and Brailsford 2003).

This paper proposes the use of hybrid simulation in healthcare. From Hybrid simulation the authors mean integrated use of SD and DES (SD+DES). As health care organizations are complex and integrated, decision making is facing challenges. In order to make better decisions and get better insight into the system, it is important to understand intra–departmental as well as inter-departmental interactions. In addition to these horizontal interactions, it is also vital to analyze and align the vertical interactions (such as between strategic level and operational level). The authors argue that this horizontal and vertical alignment can be achieved by deploying hybrid (SD+DES) simulations. Such hybrid models will be able to model stochastic, continuous and qualitative aspects of the system. They will aid the policymaker in evaluating the impact of their decisions from both strategic and operational perspectives.

Hybrid models function like bouncing models in which information is bounced between SD and DES components of the models (Fig 3).

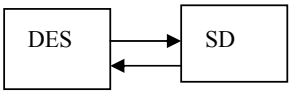

Figure 3: Interaction between SD and DES component

Depending upon the way SD and DES represents different aspects of the system and the context in which they can be used in healthcare, the authors have proposed three different formats: Hierarchical Format, Process - Environment Format and Integrated Format.

Table 3.1 provides brief description of these formats.

Table 3.1 – Hybrid (SD + DES) Formats

Hybrid Format	Description
Mixed continuous and discrete format	Some elements of the organization are represented with SD and some with DES without clear distinction.
Process – Environment	Process is represented with DES and Environment factors with SD.
Hierarchical format	SD is used for strategic level and DES for operational level decisions.

3.1 3.1 Hierarchical Format

In the hierarchical Format, SD is used for Strategic Level Decision Modeling and DES for Operational Level as shown in Figure 3. Strategic decisions are evaluated using SD and output of SD is passed down to the DES model.

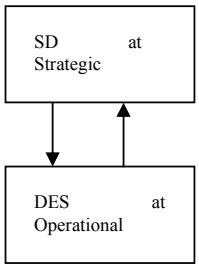

Figure 3: Hierarchical Format

DES model accepts the outputs of SD Model and use them as inputs. Outputs of DES models such as waiting times, throughput and time in systems are passed to the SD model. This cycle of passing information to each other continues till a synergy between SD and DES is achieved. Some examples found in manufacturing (Helal and Rabelo, 2004; Rabelo et al, 2005; Venkateswaran et al, 2005) can be categorized under this format. This format can be used for the feasibility analysis of strategic initiatives from the operations perspectives and vice versa.

3.2 Process Environment Format

In the process – environment format, DES is used for modeling the process and SD is used for modeling environment surrounding the process (figure 4).The DES model optimizes the processes and passes the outputs to SD. SD captures the turbulence created in the environment as a result of process optimization This cyclic process continues till both SD and DES align with each other.

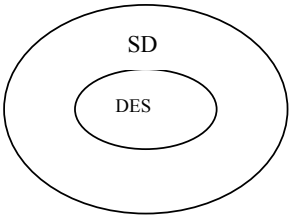

Figure 4: Process – Environment Format

The process Environment Format is based on the ideology that healthcare processes are evolving and the environment, just like Darwinian Theory of evolution, has impact on the evolution of processes. For effective and sustainable decisions, it is vital to consider the impact of environment on process and vice versa. In healthcare context, during the exercise of patient pathway reforms, DES can be deployed to evaluate the alternative options for re-engineered processes and environment surrounding the pathway can be abstracted by using SD. Outputs of reformed processes are fed into environment abstracted by SD. The impact of environment turbulence is passed down to process. Martin and Raffo (2002) have provided a good description of utility of this format in the context of software project management.

3.3 Integrated Format

In the Integrated format, there is no clear distinction like strategic with SD and local with DES in hierarchical and process with DES and environment with SD in process-environment format. In the mixed format, some parts of the system are modeled using discrete and some are modeled using SD. There is no clear demarcation and guidance for distinction between SD and DES elements of system. Lee et al (2002) modeled supply chain using both SD and DES. His approach can be categorized as mixed hybrid format.

Detailed discussion about the transfer and conversion of data between SD and DES models is out of the scope of this paper, as the focus of this paper is more on classification and applicability of various hybrid simulation formats to different modes of governance in UK healthcare. Details of interaction and synchronization of information between SD and DES is the focus of current research and will be published in a future publication.

Hybrid simulation will aid in forming a synergy between strategic and operational management. Management will be able to use these models to evaluate proposed policies prior to their implementation. The model will also be able to represent the ripple effect of optimization and streaming of processes on the environment and vice versa. These hybrid models will represent the system from both "zoom in" and "zoom out" views capturing the intra-organization detail as well as inter-organization interactions. It has been argued that inter-organization interactions are shaped by the overall system design (Rhodes 1998). The next sections will provide a brief description of different modes of governance and the applicability of hybrid simulation to these governance styles in order to make effective decisions.

4 GOVERNANCE IN UK HEALTHCARE AND HYBRID SIMULATION

The UK healthcare system is complex consisting of a large number of diverse organizations. Although these organizations correlate with each other in order to provide service delivery to its customers, it is a known that inter-organization interaction has been imperfect and problematic (Webb 1991). As reported in the previous section, interaction between organizations is shaped by the environment created by overall modes of governance.

4.1 Modes of Governance

UK Government policy over the last two decades reveals shifts from "hierarchies" to "markets" and then to "networks" (Rhodes 1997; Smith 1999; Pierre and Paters 2000).

Current UK healthcare system design exhibit cocktail of all three modes of governance, each of these three have different implications on the inter-organization interactions and cooperation (Rhodes 1994; Sullivan and Sketcher 2002; Ferlie and McGivern 2003).

4.1.1 Top down Performance Hierarchical Management Mode

In this mode all the healthcare is delivered by one large, vertically integrated organization. It has-been argued that in NHS such hierarchical mode of governance has been intensified over the last two decades (Ferlie and McGiven 2003). When the NHS was formed in 1948, the relationship between the NHS and the government was more like "Command and Control", where the entire decision-making was pivoted around Whitehall (NHS plan 2000). Recent Example of this command and control mode is the introduction of Strategic Health authorities (SHAs). SHAs are seen as vehicles for the management of NHS trusts and primary care groups. This mode of governance is associated with a strong performance management system. Performance measures such as waiting times are recent examples of this hierarchical control. In this mode targets are set by strategic management and passed on to the operational management

4.1.2 A Network Partnership Mode

In appreciation of the fact that most of the operational activities rely on the decisions made by frontline staff rather than Whitehall, Tory Government replaced the hierarchical mode of governance by "internal market" approach. It resulted in fragmentation and variation of standards within the NHS. The rigid institutional boundaries and isolation of individual hospitals and primary care services from one another hampered the planning across NHS as a whole. When the labour government got elected in 1997, they tried to resolve this problem of planning across NHS by introducing network partnership mode of governance, which emphasized on the need for collaboration and cooperation.

This mode stresses on collaboration, managed networks, care pathways and partnership working. NHS Modernization agency has been promoting the redesign of healthcare. In order to add value especially the value experienced by the patient, it has been sponsoring process redesign interventions to reconfigure the whole patient pathway. The focus on whole pathway as compared to different processes with in delivery programme requires an integrated perspective. In this mode there is more emphasis on horizontal integration as compared to vertical. Managed cancer networks are examples of network partnerships mode.

4.1.3 Quasi-Market Mode

Quasi-market differs from the pure market in the sense that it is a managed market rather than pure market. The period between 1991 and 1997 is characterized as the period of quasi-market (Ferlie and McGivern 2003). In this period NHS was fragmented into commissioners and providers who are related to each other through a contract rather than hierarchical command and control. In view of quasi-markets promoting fragmentation in healthcare labour government replaced this by network partnership mode. Recently there has been a limited shift back to quasi-market mode of governance with increased diversity on the providing side. The signing of contract between NHS and private sector in October 2000 to reduce the waiting list can be classified under this mode (Ferlie and McGivern 2003). Quasi-market mode is more of a support of conventional hierarchical managerial performance management rather than promoting real competition. It differs from conventional markets in the sense that in pure markets contractual coordination between organizations is incentivized purely on the basis of price without any element of hierarchical or network based modes of governance.

4.2 Applicability of Hybrid Simulation to different modes of Governance

This sub-section focuses on the applicability of the proposed hybrid approach to decision making in various modes of governance in public healthcare.

4.2.1 Top down Performance Hierarchical Management Mode

There is a growing concern regarding the gap between policy and practice (Wolstenhome et al. 2007; Northcolt and Llewellyn 2003). The proposed hybrid approach can assist healthcare providers in addressing this gap proactively. The use of SD for the evaluation of strategic policies and DES for evaluation of operational decisions in Department of Health has been reported (Halsall 2007). Although both strategic and operational decisions are evaluated but there is no alignment between the two because they are not evaluated in context of each other.

This isolation poses challenges to the sustainability of strategic initiatives due to mismatch between strategic policies and operational capabilities. Recently it has been reported that this difference in targets set by strategic government and the ability of operational level has resulted in informal reactive coping policies (Wolstenhome et al. 2007). In this strict regime of fame or shame based on meeting targets, it has emerged that managers are adopting informal policies which compromises on the safety standards in order to meet these targets. Falling patient confidence in the system are some of by-products of these informal policies. It has been reported that decrease in waiting times is consistent with decrease in people's trust in public health (Parker 2007).

Though it is difficult to collect data on such informal policies it has been reported that in order to meet waiting

list targets, doctor's referral rate decreases with increase in backlogs. Another example of such misconduct is early discharge of patients. These informal policies are short term reactive measures which can do more harm than good. One of the unintended consequences of these early discharges is readmissions. These reactive measures pose challenges to the sustainability of strategic policies.

The authors argue that in this top down Governance mode where targets are set at strategic level and passed down to operational level, hierarchical format of hybrid simulation can help decision makers in foreseeing the implications and feasibility of strategic policies from an operational perspective. By using SD strategic management can evaluate the strategic options and pass down the output to DES model for operational feasibility analysis, the output such as waiting time, throughput, backlogs, resource utilization are fed back to SD model. This cyclic process goes on until both strategic and operational options align with each other. In nutshell hybrid simulation can help strategic management in making more effective and sustainable policies.

4.2.2 Network Partnership Mode (horizontal interaction)

In this mode of governance the emphasis is on whole patient pathways which comprises of collaboration between different organizations. The authors argue that a proposed process - environment hybrid format can be deployed to optimize the pathway and foresee the ripple effects of that optimization. As the hybrid approach can reveal the unintended consequences, healthcare providers can address them proactively. From their discussion with one of their project exemplars authors have come across a recent example of process reforms, where sustainability of reforms has become a challenge for the management. It is an example of cancer networks which were experiencing long delays in the treatment due to the cumulative effect of distance traveled by the patients and intrinsic characteristics of cancer decision making, which require the presence of primary, secondary and tertiary cancer experts. Due to the distances between the physical locations of these experts, this process of joint decision making was experiencing delays. As time is critical in cancer treatments, healthcare providers respond to this problem by using a video - conferencing tool. This improved the process many folds by eliminating the need of all experts to be in close physical proximity during the process of decision making. This further alleviates the need for patients to travel long distances. The process reform was a complete success and it worked very well for quite some time.

The optimization of process caused ripples in the environment by changing stakeholder's behavior, as the delay and backlog was decreased, primary teams started referring more patients, due to the success of this one network, other networks started adopting the same technology. All these environmental changes start impacting the process pathway by putting extra burden on tertiary teams which is scarce resource. Tertiary teams due to these additional demands are struggling to cope. The authors argue that hybrid simulation can help healthcare providers to visualize and address these issues proactively rather than reactively.

In the Process-Environment hybrid format, DES component due to its synergy with process context will aid decision makers in the optimization of process. The outputs of optimized process in the form of waiting times and queues etc are passed to SD model representing the surrounding environment. SD will analyze the effects of this optimization on environment in which it operate and passed down the turbulence, "increased demand for tertiary services" in the context of cancer network to the process. The DES model evaluates the optimum level of resources required for increased demand. This cycle of exchange of information between SD and DES continues until their outputs and inputs align with each other.

4.2.3 Quasi-Market Mode

Optimization of service delivery with constrained resources and adherence to performance measures requires a knife edge balance. The hybrid approach can not only assist organisations in optimizing their processes but also help managers in optimizing their resource allocations. DES in the hybrid framework captures the uncertainty and optimizes the processes. SD components assist in optimal allocation of resources. From Optimal allocation, authors mean the allocation of resources to that segment of overall delivery pathway where it adds maximum value. Once their internal processes and resource allocation has been optimized, healthcare providers can identify the gap between their capacity and demand. This gap can be fulfilled either by increasing in-house capacity or buying services from the available providers.

Wolstenhome et al. (2004) on the basis of SD evidence proposed to the government that in order to meet the demand the policy of investing in social care in order to accelerate discharge is more effective than investing in increasing hospital capacity. The drawback of this model lies in its ability to give clear directions to operational level. Rather than aggregate guidelines such as accelerated discharge, operational management require detailed and clear action points such as which patient attributes qualify them for discharge. The SD model struggles in capturing that detail. The result of this was that in order to align with strategic agendas and posed demand, operational mangers cope by discharging patients early. These early discharged not only put pressure on the social services which some times have to buy capacity for private providers which works out to be far more expensive than increasing hospital capacity. These early discharges also result in re-admissions which further aggravate the occupancy levels. The authors argue that all these issues could have been addressed more effectively and proactively if the decisions makers had a tool which could evaluate the strategic and operational options in an integrated manner. The authors argue that hybrid simulation can assist both commissioners and providers in evaluating their buy or not to buy options more effectively.

5 CONCLUSIONS

In this paper the authors have attempted to set a context for the need of a method which can address the complexity of healthcare organisations. Authors have provided an overview of use of DES and SD and their limitations in context of healthcare. Although SD, due to its macroscopic view have provided some reliable models for understanding the system from holistic perspective (Lane et al. 2000, Wolstenhome 1999, Wolstenhome et al. 2004; Homer et al. 2006), it faces challenges when these models are seeked for providing granularity required for operational actions. Similarly DES, due to its ability to capture detail and variations has been effectively used for the problems of narrow focus, its applicability to problems of wider focus is questionable. Limitations and capabilities of both SD and DES are quite complementary to each other. In appreciation of detail and the dynamic complexity of healthcare and complementary nature of SD and DES, the authors have proposed the use of hybrid simulation (integrative use of SD+DES) in healthcare. The authors have proposed three possible ways of using hybrid simulation in healthcare: Hierarchical format, Process _ environment format and integrated format.

It has been argued that effective decision making require abstraction of detail up to individual level as well as abstraction of dynamic interactions between different departments and organisations. Dynamic interactions between different organisations are governed by the design of governance. It has been reported that present healthcare governance is a mix of three different modes of governance: Top down Hierarchical Mode, Network Partnership mode and Quasi market Mode. In appreciation of these designs of governance and their impact on interactions, the authors have attempted to provide a description of the applicability of hybrid simulation to these modes. In nutshell it can be concluded that hybrid simulation can aid decision makers in making effective and sustainable decisions.

ACKNOWLEDGEMENT

This study is supported by The Multidisciplinary Assessment of Technology Centre for Healthcare (MATCH), which is funded by EPSRC Grant GR/S29874/01).

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AUTHOR BIOGRAPHIES

KIRANDEEP CHAHAL is a research student at the Centre for Applied Simulation Modelling (CASM) in the School of Information Systems, Computing and Mathematics, Brunel University, Uxbridge, United Kingdom. Her research interests are in modelling information systems, decision making in Organizations and modelling Biological systems. Her email address is <kirandeep.chahal@brunel.ac.uk>.

TILLAL ELDABI is a senior lecturer at Brunel Business School, Brunel University, UK. He received a B.Sc. in Econometrics and Social Statistics from the University of Khartoum. He received his M.Sc. in Simulation Modelling and his Ph.D. from Brunel University. His research is in aspects of healthcare management and the intervention of simulation and his main research also concentrates on the economy of healthcare delivery. He is looking to exploit the means of simulation on the wider information systems management area to assist in problem understanding. Dr. Eldabi's email address is <tillal.eldabi@brunel.ac.uk>.