Journal of the Operational Research Society (2007) 58, 262–270

www.palgrave-journals.com/jors

Simulation modelling in healthcare: reviewing legacies and investigating futures

T Eldabi*, RJ Paul and T Young

Brunel University, Uxbridge, Middlesex, UK

This article proposes considered futures for the use of simulation as a problem solving technique within healthcare settings. Using a synthesis of trends identified by a selection of experts in the field, academics and industrialists, critical analysis was applied to find the differences between what exists and what could be created based on outlining some major themes. The survey data reveals that most respondents agree on following whole system approaches with more joined up modelling or mixed methods to tackle problems rather than single-solution-based practices. The article then presents options for how simulation could be used within the healthcare domain. Such options or futures could assist in identifying the critical barriers towards having a successful strategy and provide the basis for debate that will be necessary to attain it.

Journal of the Operational Research Society (2007) **58,** 262–270. doi:10.1057/palgrave.jors.2602222
Published online 21 June 2006

Keywords: health care simulation, model implementation

1. Motivation behind this paper

In this paper we use our own experience in simulation modelling, the opinion of experts and the literature to argue that the immense potential of simulation has not been realized in practice. We have observed this in our combined 40 to 50 years experience (Lehaney and Paul, 1996; Lehaney *et al*, 1999; Page *et al*, 2000; Kuljis *et al*, 2001; Rodgers *et al*, 2003), and in this paper we polled a number of experts to give substance to this lost potential for simulation modelling in healthcare. In addition we review the literature. By simulation, we are referring to the widest possible range of simulation and modelling techniques, from spreadsheets to discrete event simulation and system dynamics. We then argue from this synthesis some possible futures for simulation modelling in healthcare. We use the plural word 'futures' deliberately since even with the experience to hand, prediction would be fragile. However, we offer a range of possible ways forward for debate, agenda shaping and possibly therefore facilitate the emergence of more effective use of simulation modelling in healthcare in the future. These futures are not a contribution to knowledge in the classical sense, since they are untested and even difficult to substantiate. Our intended contribution is to initiate the debate in the stakeholders' communities that, while possibly leading to socially constructed approaches to the use of simulation modelling in healthcare, will have given a strategic structure for constructive development and research in the area.

*Correspondence: T Eldabi, School of Information Systems, Computing and Mathematics, Brunel University, Uxbridge, Middlesex, UB8 3PH, UK.
E-mail: tillal.eldabi@brunel.ac.uk

This article provides background, vision and analysis around the application of simulation to such ideas as systematic process redesign, delivery and roll-out across the healthcare sector. We start by providing an overview of health services in the UK as a contextual example, followed by a brief review of potential benefits of simulation in healthcare. The section after that introduces and discusses the qualitative responses obtained from respondent expert views regarding possible directions of future of simulation. We move on to analyse the data from which we reason and suggest ways of using simulation wider within healthcare more effectively. The paper concludes by offering to debate the collective 'wisdom' of all the direct and indirect participants in this paper as to the challenges and possibilities for simulation in healthcare.

2. The UK healthcare economy example

Healthcare organizations have become large and complex as societies have become wealthier and medicine continues to improve. The NHS spends over £70 billion per year, is projected to exceed £90 billion by 2007/2008 (DoH, 2006) and employs more than a million people. Moreover, there are a myriad specialist teams, sometimes interlinked in the most arcane manner. Served communities are typically millions of people and every one of us is a potential patient. NHS has pursued quality healthcare delivery and universal provision for more than 50 years. To do so, it has partitioned delivery into a generalist primary care sector offering local access to patients, and a secondary (or even tertiary) care sector, essentially offering hospital-based specialist services. However, changing demographics and increasing public

expectations are putting financial pressure on the system. In response, the NHS along with other such organizations around the world has been frequently redesigning care delivery. We observe that all these attempts at improvement are essentially empirical with little attempt to realize the potential for simulation to help.

Adoption and standardization of service delivery has taken methods from other sectors (including manufacturing) and adapted them to the healthcare scene. This has resulted in a series of improvement guides (DoH, 2006) and the recent publication of the *10 High Impact Changes for Service Improvement and Delivery* (NHS Modernisation Agency, 2004a). In essence, these recommend an incremental approach based on the Plan-Do-Study-Act (PDSA) cycle (Rawlins and Littlejohns, 2004). The Modernization Agency, which was set up in 1998 to drive such change (NHS Modernisation Agency, 2005) no longer exists, and its improvement role has been distributed across the NHS, some elements being absorbed into local improvement teams and some into the much smaller NHS Institute for Innovation and Improvement (2005). This institute also has responsibility for rolling out best practice, as well as for training and leadership development.

Given the nature of the constraints in healthcare, is it worth seeking improvement strategies that reach beyond the local improvement team, and methods that may address a wider set of levels for improvement (from the local to the strategic)? If so, we should look at system-integration communities and adopt simulation-based approaches, since they are used to conflicting constraints and high levels of complexity. As well as possibly short circuiting improvement cycles that might take years to prove out and providing a risk-free environment in which to understand change, simulation can offer significant benefits when confronting complex or multifaceted design issues (Rawlins and Littlejohns, 2004).

A critical question is whether the delivery community would wish to adopt simulation in any form as a methodology for improvement. There is a considerable amount of evidence for a divide between simulation communities (Delesie, 1998; Royston, 1999; Fone *et al*, 2003; Dodds, 2005) on the one hand, which see obvious benefit in applying their methods and skills to healthcare redesign and delivery, and the healthcare service providers, which favours more experimental and heuristic approaches—certainly in its published guidance. However, there is little in the mainstream academic literature about how to tackle such a division or to suggest potential consolidation for enriching the relationship between theory and practice in this field. Therefore, as well as surveying the literature, this paper, broadens its scope to ask some experts in the UK and North America about their views of the trends in simulation. It is clear that this community is turning its attention to facets of applied simulation which are not well articulated in the literature. Moreover, the experts polled acknowledge some of the division, alluded to above, and has some ideas for bridging it from the simulation modellers' side.

3. Simulation and healthcare service legacies

3.1. The growth story

Simulation modelling is widely used in military and manufacturing sectors, to the extent that it sometimes represents a vital part of any planned project. On the other hand, simulation has only recently started to gain acceptance in health sector, despite its introduction over 30 years ago (Fone *et al*, 2003). Geoff Royston (2005) in his presentation at the MASHnet (2005) launch—a research network to enhance collaboration between modellers and problem owners—provided evidence of the increase of the use of simulation in healthcare settings. He alluded to the fact that (Jun *et al*, 1999) found only 8 studies in simulation of health clinics between 1973 and 1977, while there were 28 studies between 1993 and 1997. He also adds that the number of citations increased dramatically after 2000, according to Google™ Scholar. Figure 1 shows the trend of citations of simulation in healthcare as presented by Geoff Royston (2005). The following discussion shows how simulation has been used in many aspects of healthcare.

3.2. Uses of simulation in healthcare

The various areas of applications that have been pursued and documented make evident the extent to which simulation could be used in healthcare. They vary from decisions directly associated with medical issues, to those of a more administrative or operational context. Models have been created for the analysis of chronic diseases such as diabetes, HIV/AIDS, sexually transmitted diseases, cancer, and heart disease—with the majority based on HIV/AIDS (Dangerfield and Roberts, 1996, 1999; Lagergren, 1998). Simulation models have been used to explore control schemes, predict future incidence, prevalence and mortality for these diseases as well as monitor their progress for assistance in deciding on patient-specific treatments (Lagergren, 1998). General treatment schemes have also been analysed by researchers, for example, the evaluation of adjuvant breast cancer treatment

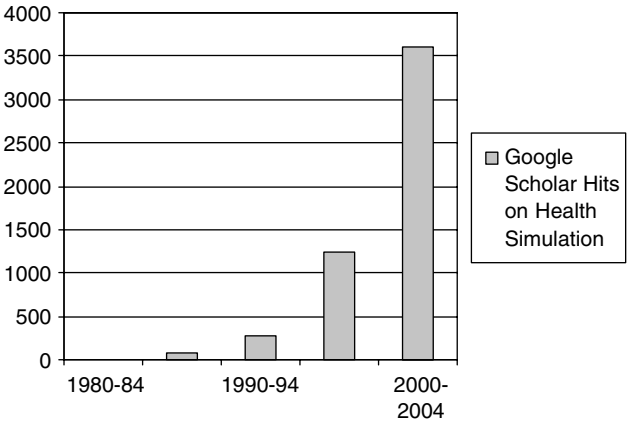

Figure 1 Trends of citations of simulation modelling in health (Data Source: MASHnet Launch Presentation; Royston, 2005).

(Brown *et al*, 1999; Eldabi *et al*, 2000). These studies used simulation to model the complex pathways of treatment and compared alternatives for effectiveness, in terms of costs and the patients' quality of life (Eldabi *et al*, 2002). Fone *et al* (2003) note the prevalence of simulation that has taken place within the hospital setting. A special case of this has been the accident and emergency (A&E) department, where a wide variety of methods have been applied (Brown *et al*, 1999; Eldabi *et al*, 2000, 2002; Lane *et al*, 2000; Coats and Michalis, 2001; Cooke *et al*, 2002; Brailsford *et al*, 2004; Connelly and Bair, 2004, Lattimer *et al*, 2004). Applications for operational decision support are also widespread and have become increasingly significant as calls for improved performance grow. Most of these undertakings have focussed on departmental operations; especially the more patient-intensive ones such as outpatient and emergency departments. The main objective is usually obtaining effective and efficient patient flow, which means high patient throughput, low waiting times, short length of stay and low clinical overtime (Jun *et al*, 1999). According to Jun *et al* (1999), there are three major areas in which simulation can benefit patient flow:

- It offers the opportunity to more effectively define and scope the range and nature of potential benefits from a redesign proposal or innovation. This might include relevant metrics and the means to measure them.
- It can provide deeper insights into the barriers and incentives to adoption (and hence spread of good practice) that could subsequently be tested in field environments.
- It provides an environment where the final products can be 'bench-tested' with teams of NHS staff prior to more formal release into service.

On the administrative side, simulation has been used to estimate a hospital or entire health area's future resource needs and the required expenditure (Fone *et al*, 2003). When resources are scarce, simulation proves useful for investigating the minimization of resources for cost control, while maintaining quality. Jun *et al* (1999) describe work on staff and bed planning where the goal was to have sufficient levels of these resources to meet demand while ensuring that utilization rates were high, and studies that investigated the efficacy of new constructions, expansions or integration of hospital facilities.

Policy has generally been based upon other types of research (Pitt, 1997; Royston *et al*, 1999; NHS Modernisation Agency, 2004b). Sanchez *et al* (2000) explain that the implications of policy changes are rarely investigated, although there are some examples of such planning and modelling (Royston, 1999); however, these were always published in academically refereed journals. Public policy models seek to evaluate strategies that authorities may have in mind and simulation modelling is an ideal method of doing such. Standridge (1999) refers to studies undertaken in order to assist in establishing policies for allocating donor livers to patients needing transplants and models created to predict healthcare staff requirements to support decisions on admittance numbers to medical schools in the United States.

3.3. Weaknesses

Simulation in healthcare as an academic subject has been widely explored and well documented (Jun *et al*, 1999; Fone *et al*, 2003) although, as we have seen, the obvious user communities prefer other methods, perhaps viewing it as a solution in search of a problem. Dodds, a practicing clinician and champion of simulation techniques, notes resistance to simulation by the healthcare community and suggests two possible reasons (Dodds, 2005). First, he notes the difference between people, with their unpredictability and distaste for queuing, and 'widgets,' which progress in orderly fashion from 'work-centre' to 'work-centre.' He wonders whether this difference places a limit on the applicability of methods designed to address the latter to the world of the former. Secondly, he identifies training in simulation as an enabler for healthcare professionals, while the lack of it as a significant barrier to adoption.

The relationship between simulation and healthcare systems ought to be symbiotic. However, the impact that simulation has on policy-making or, at a lower level, managerial decision-making is weak. While it is possible to assess simulation benefits on defence and manufacturing systems, such benefits seem less tangible when it comes to healthcare simulation. It is obvious that the marked increase in the use of simulation is not matched by implementation or more formal recognition by policy makers. Fone *et al* (2003) suggest that implementation of simulation results is minimal among the studies they have reviewed, mirroring the conclusions of 22 years earlier articulated in a review conducted by Wilson (1981). The following section represents the initial steps we took in order to draw attentions toward potential improvement to implementation of simulation in healthcare systems.

4. Synthesis of collective wisdom

In order to determine the state of play in simulation and potential future, we asked a selection of experts to identify the critical trends in the current simulation scene (Eldabi *et al*, 2004). The experts were picked on the basis of the extensive experience of the authors: a total of 12 UK academics, 4 North American academics, and 6 UK companies of various sizes from small consultancies to major simulation providers. There was a high response rate, but not everyone answered the question on current trends. The experts were not rationed to one per institution, and specifically excluded anyone from the authors' institution. Some experts were known primarily for their simulation and modelling record, while others were primarily healthcare modellers. Table 1 shows the relevant and shortened qualitative responses from the 13 experts who gave their views on the trends and potential benefits of simulation to healthcare systems. It is evident that in being asked

Table 1 Responses to the question: What is the current trend as you perceive it?

Respondent 1	Taking a 'whole system' view—it is necessary to consider the links between component parts of the health care system rather than view each in isolation. Taking a multidisciplinary view—teams of researchers with different backgrounds and perspectives. Combining qualitative and quantitative approaches. Including the 'human element; in simulation models.
Respondent 2	Wait time management and accountability are major current issues in North America.
Respondent 3	For problem structuring of healthcare interventions using qualitative modelling, little theoretical progress appears to be being made from the earlier work of a decade or more ago. The recent EPSRC Report on OR mentioned healthcare applications as a particular area of international strength; the panellists of the most recent RAE identified soft OR as one of the very few areas of modelling in which the UK appeared a 'world leader'. For knowledge transfer modelling (for example, the modelling of organizational memory) the work on narrative appears to be growing in importance, and seems likely to continue to do so.
Respondent 4	Appreciation of the need to consider a wider systems perspective in health care interventions
Respondent 5	Research on combining DES and SD approaches to incorporate the benefits of both techniques and model large complex interconnected systems (such as the use of SD to model large populations and trends, while DES captures lower level planning detail such as A&E resources, beds, etc)
Respondent 6	Further development and application of current techniques such as Bayesian methods, MCMC, DES. A move away from the perception that 'one method fits all'—further collaboration across the domain with the use of techniques or combinations of OR techniques and wherever necessary development of hybrid techniques and methodologies. Trend in the healthcare domain appears to be focused on metrics, improved performance, cost effectiveness analysis, more accurate predictions of future activities for better resource utilization.
Respondent 7	Towards developing complex systems models based on data from disparate data sources.
Respondent 8	It is vital that current expenditure in health care provides value for money and much of the problem lies in the delivery chain. There is a need to be much more ambitious and to develop whole system approaches to this delivery chain. This requires a rare mixture of hard and soft approaches. The technical work could be done in system dynamics, discrete simulation or some combination.
Respondent 9	Fast development particularly in the area of modelling for Health Technology Assessment as part of the NHS HTA Programme. Need for much greater integration between disciplines (eg Health Economics and Operations Research community).
Respondent 10	Continued migration of industrial tools and techniques into healthcare planning and management. However, much work needs to go into softer skills to help implement 'new' techniques and to address the real and current issues of healthcare. Data quality issues will also need to be addressed.
Respondent 11	Modelling will remain a marginal influence in the planning and delivery of healthcare services until (a) IT systems are improved, (b) data quality is put to the top of the agenda, (c) health services managers attach more importance to the topic.
Respondent 12	A realization that modelling and in particular SD Modelling has a significant contribution to make to whole system decision-making in an ever increasing 'partnership environment' for example, More pooled budgets, LSPs, LITs, Health Act Flexibilities, Children's Trusts, Criminal Justice System, etc. A move towards mandatory System Dynamic modelling as part of the strategic risk management appraisal of major business cases across the public sector.
Respondent 13	Generic models specific to departments—for example, Pharmacy, theatre, day surgery, A&E, ward/bed scheduling. For example, our generic Pharmacy model has been developed with Bristol Royal Infirmary

for critical current trends, they have interpreted the question in different ways—that is, responses ranged from statements of what they believe in, to expressions of what the exact issue may be. For confidentiality reasons we opted to omit the identity of the respondents and any parts of the responses that may provide hints as to who they are, without disturbing the overall meaning.

The interesting feature to emerge from the expert opinions is that a common set of themes echoes that of the literature. A strong theme that emerged from these experts is the desire to follow a whole system approach from both a delivery (Respondents 1, 4 and 8) and a simulation perspective (Respondent 1), this is articulated both by:

- those who aspire to mix modelling techniques more readily (Respondents 5, 6 and 8) or even work across disciplines (Respondent 9),
- those who are asking for a range of building blocks to cover a wider set of healthcare delivery functions (Respondent 13), and
- those who are seeking a way of using data from disparate sources (Respondent 7).

The present fragmented modelling base has enabled considerable progress to be made, but expert opinion is clearly looking forward to a set of techniques, or a framework (see also Respondent 3 on problem structuring) that addresses the full complexity of care delivery and embraces the diversity of the modelling techniques. Since there are clear difficulties in achieving this, this is clearly an agenda for the future, rather than a statement of a problem solved.

Against this, there are voices calling for a greater use of specific methodologies—be they soft systems (Respondent 3) or System Dynamics (Respondent 12). In some senses, these

respondents appear to prefer to focus on a single methodology, in order to better address the broader dimensions of the healthcare problem. We interpret this to endorse an holistic approach to the problem, while presenting an opposing perspective on the means. Within such a community it is inevitable that such tensions exist; however, one might argue that the field of agreement is broader than the differences within the communities. Overall, however, the weight of opinion gathered appears to lie with those seeking to mix methodologies, rather than those seeking to expand a single methodology to cope with the whole system.

Another set of responses concerns the greater uptake of simulation methods by the healthcare delivery communities. Not surprisingly, many see the benefits of applying simulation—for instance, in addressing waiting lists (Respondent 2), setting metrics (Respondent 6), supporting the quest for value-for-money (Respondent 8), as well as helping organizations collaborate in care delivery systems (Respondent 12). Against this, is an awareness of barriers to adoption, some of which are implicit within the issues already identified with the fragmented simulation base and absence of appropriate tools. However, there are also questions of data quality (Respondents 10 and 11) and a feeling that the community is not at ease with modelling tools (Respondents 11 and 12).

5. Investigating futures

It is not possible to guarantee that opinions of the above 13 experts are typical of all academics and practitioners who are working in the area. Moreover, the views of these experts, while insightful, are unlikely to explore a number of critical issues. For instance, as suggested by one of the anonymous referees, it is possible that one of the cultural divides between the clinical and operational communities within healthcare on the one hand, and the academic and OR communities on the other, concerns expertise and the difficulty outsiders have in recognizing or analysing its impact. Similarly, the ability (or inability) of managers and senior clinicians to conceptualize local difficulties in terms of system-level problems, may also contribute significantly to the cultural divide. In particular, many managers will tend to be driven by targets, budgets, firefighting and episodes to do with patient journeys, or focusing their attention on patching up inter-disciplinary divides. None of these issues is likely to emerge from consulting this cohort of experts. However, it is evident that there is a qualitative consistency that forms a trend when going through the above responses. This level of consistency makes us confident that most of the above answers resonate with the general trend within the community. There is clear evidence that all experts agree that there are some gaps and barriers against implementation of simulation in the healthcare are. From the responses we feel that there are three main themes under which these gaps can be classified: *modelling perspective*, *communication issues*, *and organization of simulation expertise*. This section attempts to provide analysis of the responses based on which the major gaps could be identified and classified following these themes. Based on this we will prioritize and recast the position in terms of barriers which, if overcome, would enable the community to respond to the challenge for the NHS.

5.1. Theme 1: Future modelling perspective potential

While hospitals represent a suitable context for modelling in that data is relatively easy to gather and studies may be kept to a reasonable duration, there is an increasing awareness that methods are required that reach beyond the hospital boundary. Evidence of this awareness in the polled community is found, for instance, in the emphasis on the 'whole system', on pathways and patient flows, and on cross disciplinary research found in the responses. It is not clear that the existing tools can cover the breadth of this requirement and it is possible that new methods or interfaces will have to be synthesized. The judgement of the authors is that, since the NHS is increasingly focusing on process, most of the basic methods probably exist because they were developed to improve processes, albeit in other sectors (Young *et al*, 2004; Baldwin *et al*, 2005). One area of coverage for which there appears to be a gap is that of human behaviour, especially as related to patient choice. Some progress is being made (Huang *et al*, 1995; Mea, 2001; Brailsford and Schmidt, 2003) to incorporate human behaviour into standard methods, but this is early evidence that the problem has been identified. In view of the political emphasis on choice, this is a significant gap.

More practically, while there are interfaces and packages based on the more commonly used methods, there is a lack of robust, easy-to-use tools that could readily be used by clinicians and hospital managers. Dodds (2005) offers a view on the functions and interfaces that might help. While some believe that an essentially stochastic modelling activity will always need expert support, a second generation of packages with user-cantered set-up and self testing would be a desirable step forward. As noted above, this is reflected in the views of some of the respondents, recognizing the need for better IT systems and higher quality of data. A solution in the opposite direction would be to fill this gap by developing ways of grabbing appropriate models, gluing them together and creating a sort of quick-and-dirty, disposable modelling (Eldabi and Paul, 2001). This would achieve higher levels of accessibility and responsiveness, although this might be at the expense of accuracy. This raises the question as to what sort of 'accuracy' is required, and whether modelling accuracy guarantees a good solution. Anecdotal evidence, and that found in the literature suggests that dialogue around setting up the problem is often the most important element (Eldabi *et al*, 2002; Dodds, 2005).

Developing this theme, and building on the 'whole system' concept reveals a further gap in terms of an overall framework. For instance, it is not clear how one might 'plug' different

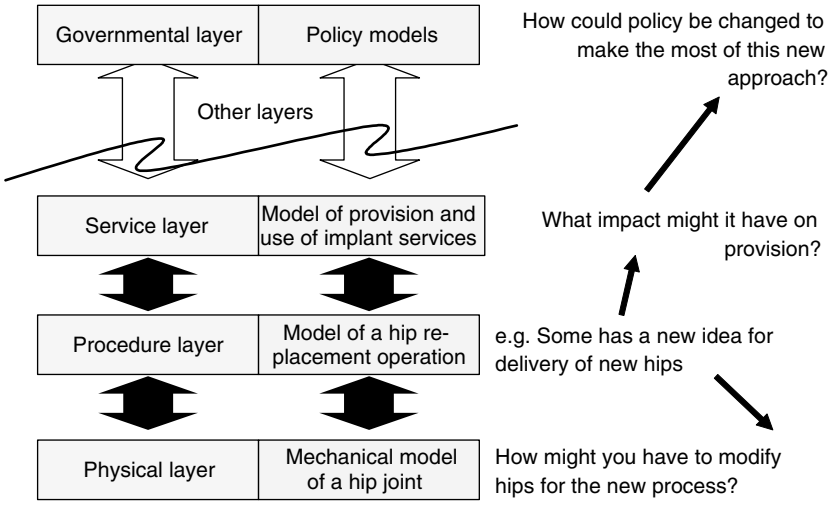

Figure 2 An example of multi-layered modelling.

simulations together—an issue which several respondents are considering. Beyond this lies the question of whether a conceptual framework might be constructed, within which such 'plugged together' models might operate. The military community (Beckett, 2000), for instance, has created a multilevel framework that enables simulation to be performed at different levels (eg individual missions, fleet engagement, geopolitical events), with ways of passing information from one level of simulation to another.

By way of example, Figure 2 shows various perspectives on hip replacement—from the physical aspects of technology and placement, through to policy and national provision. There are appropriate modelling techniques for each of these, although policy models, for instance, would tend to be quite different from physical models of hip behaviour. Process models addressing the intermediate layers might focus on logistics or service provision. A further element of the framework might be to allow cooperative modelling, with large numbers of participants operating from diverse facilities, possibly invoking a range of different models. Such models could be small or big, simple or complex, holistic or specific. It is worth emphasizing that the approach to modelling should be driven by the problem at hand rather than the available modelling skills. In this field the impact of modelling is more important, and not necessarily proportional to the complexity of, the model itself.

Building on the category of costs and economic evaluation identified in the systematic review already cited (Fone *et al*, 2003), there is the larger issue of combining the critical elements of people, process and technology in a robust manner to provide a means of evaluating supporting technology. One of the respondents addresses this issue for evaluating IT in healthcare delivery—which means the community is starting to respond to this need. However, the authors' view is that there is still a lack of a corpus of literature and proven methods to enable the healthcare delivery community to adopt such techniques readily and routinely.

5.2. Theme 2: Improved communication between healthcare and simulation professionals

While Theme 1 considers the need to develop new methodologies and capabilities, proposing a framework, there is also a cultural issue that we believe needs to be overcome. It is not merely that the simulation and modelling community cannot currently conceptualize or offer its expertise to the clinical and managerial communities in an appropriate manner. Even if a clear framework existed that enabled problems to be partitioned by 'level' or that provided a systematic means of selecting an appropriate modelling tool for a specific healthcare task, there is still the question of demand. The perspective researched here does not really explore the demand side of this equation, but indicated that there is something missing at the communication level.

'Given the wealth of work that has already been done in this area, it is both surprising and disappointing that it has not found greater application' (Ridge *et al*, 1998). As observed above, there appears to be a communication barrier. It is likely that few modellers really understand healthcare 'from the inside' and few clinicians or healthcare managers really understand simulation. Certainly, there is no systematic appeal to simulation in the current change management programmes within the NHS, although the new Institute (NHS Institute for Innovation and Improvement, 2005) might take a fresh look at the opportunity to use simulation more extensively. Anecdotal evidence suggest that simulation is viewed sceptically overall. The PDSA approach adopted to date is mainly empirical. There are some obvious hypotheses as to why this should have happened, in that academics tend to be drawn to interesting, rather than critical problems. There

is also the question of time spent on the model at the expense of educating the customers or extracting early, imperfect results. This may endorse a view in the customer that nothing tangible is emerging from the effort. Finally, we note that there has been little systematic funding from the NHS to build a community of modellers, although the NHS retains its own in-house expertise. It is not our purpose here to compare or contrast the benefits or drawbacks of having an in-house or external community of experts. We acknowledge the extent to which some metrics and policy have benefited from the in-house analysis, but not the fragmentation of the wider community.

There are also references to the management-clinical division in the literature (Delesie, 1998) and considerable progress has been made to close it within the NHS. The difficulty it creates is that simulation might be seen as a management tool and therefore viewed with caution by clinicians and other care providers. One of the great assets that simulation has to offer is of bringing diverse groups together and providing them with a common picture of what is happening. Softer aspects of modelling could be considered here in order to facilitate more participation of stakeholders involved (Eldabi *et al*, 2002).

Finally, it is difficult for many in health systems to see beyond the boundaries in which they operate. Sometimes financial constraints explicitly forbid them from operating outside their own jurisdiction. The availability of a multilevel framework might help to address this problem. On the other hand, the problem of seeing the detail and seeing the whole at the same time is intrinsically difficult.

5.3. Theme 3: Organizing simulation expertise

It is evident from the literature and the responses that there is a body of expertise in the UK. However, it is scattered and few of the groups have the luxury of focusing exclusively on healthcare. Clearly there are at least two dimensions in which this gap must be bridged if this community is to deliver consistent, effective support. One is to provide some physical infrastructure. Whether this needs to be a national centre or whether this is an ideal application to utilize some of the GRID initiatives, is a question worth asking. The second issue is one of funding targeted research to overcome the barriers needed to connect up the potential contributors into a community that could address the NHS' needs.

6. Debate: ending the first contribution

In this paper we have attempted to move from the published *legacy* state of play in healthcare simulation to some proposal on *futures* for more effective and efficient use of simulation in this domain. Our method, rejecting questionnaire, case studies, and action research, was to seek the tacit knowledge of experts in the field. Our experience suggests that this the most likely source of useable ideas about the future than the other methods which are ideal for telling about the failures of the past. In this paper we have attempted (unusually) to fight the 'next war' rather than fighting the 'last war'. We have offered several futures but have no hesitation in predicting that we have not got it right. Retrospective insight is the only occasion when the future is shown to be wrong or right after the event. However, what we have provided, we believe, is the start of a debate about the future that will offer the opportunity to speed up the increased effectiveness for simulation in healthcare. Furthermore, we recognize that this perspective is limited, and that there is scope to contribute to this debate in terms of a better understanding of the role of expertise, for instance, or from a more organization perspective. However, in capturing tacit knowledge of experts in the field, we believe we have taken the debate forward in a useful manner. Furthermore, the provenance of this research was to provide a vision to be taken to 'customer' community, and so it necessarily approaches from that perspective. An obvious extension to this research would be to explore the cultural divide from the perspective of clinicians and healthcare managers. If you agree we are grateful for your support. If you disagree it is your turn to contribute to the debate.

To complete the paper we summarize the futures that we have investigated adding some personal prejudices to enliven the picture we have drawn:

The themes defined in the previous section represent challenges that may not be overcome in a single sweep, but through the attention and persistence from all communities involved. As a first step, more work is needed in at least bringing these communities together, and we note the recent networking programme, MASHNet, in the field. In this article, we have attempted to identify and clarify the nature of the challenges that lie beyond the networking.

Communication divides are perhaps the most difficult set of barriers to overcome. A major challenge lies in persuading service providers and clinicians that simulation, as a system level tool, can make a critical contribution. Persuading the academic community that the field as a whole is sufficiently interesting to merit research to cover the entire field—even the more mundane aspects—may also prove a barrier to a community interested in complete coverage as well as competence in the tools set.

From the perspective of the modelling community, the most pressing need is to find a starting point from which to work towards joining up different modelling methodologies, and a framework in which they might operate, for example, the Life-Cycle frame work proposed by Harper and Pitt (2004). Furthermore, there are some attempts to establish some consensus between at least two different modelling approaches (Lane, 2000) with much more tangible steps towards integrative approaches by Brailsford *et al* (2003). Furthermore, with an overall framework it is difficult to coordinate modelling capabilities or to inform, say, public health models with the results of more focused models (eg hospitals, clinics, care pathways). Perhaps the next step will be to commission methodological research in this area, to establish a widely accepted frame of reference.

Acknowledgements—We thank the three anonymous referees who reviewed this paper for their views and suggestions, many of which we have been pleased to incorporate, since these improved the quality of the article. All errors and omissions, however, are entirely owned by the author. We also thank Mark Outhwaite, Director of Technologies in Health Group of the former NHS Modernisation Agency for commissioning the exercise under which experts were polled and from which these reflective views have been behind the motivation for writing this paper.

References

Baldwin LP, Eldabi T and Paul RJ (2005). Business process design: flexible modelling with multiple levels of detail. *Bus Process Mng J* **11**(1): 22–36.

Beckett P (2000). Wargames. *Aerospace Int* **27**(11): 12–15.

Brailsford SC, Churilov L and Liew S-K (2003). Treating ailing emergency departments with simulation: an integrated perspective. In: Anderson J (ed). *Proceedings of Western Multiconference on Health Sciences Simulation*, Florida, Society for Modelling & Simulation International (SCS), San Diego, CA.

Brailsford SC and Schmidt B (2003). Towards incorporating human behaviour in models of health care systems: an approach using discrete event simulation. *Eur J Opl Res* **150**(1): 19–31.

Brailsford SC, Lattimer VA, Tarnaras P and Turnbull JC (2004). Emergency and on-demand health care: modelling a large complex system. *J Opn Res Soc* **55**(1): 34–42.

Brown J, Karnon J, Eldabi T and Paul RJ (1999). Using modelling in a phased approach to the economic evaluation of adjuvant therapy for early breast cancer. *Crit Rev Oncol/Hematol* **32**(2): 95–103(9).

Coats TJ and Michalis S (2001). Mathematical modelling of patient flow through an accident and emergency department. *Emergency Med J* **18**: 190–192.

Connelly LG and Bair AE (2004). Discrete event simulation of emergency department activity: a platform for system-level operations research. *Acad Emergency Med* **11**: 1177–1184.

Cooke MW, Wilson S and Pearson S (2002). The effect of a separate stream for minor injuries on accident and emergency department waiting times. *Emergency Med J* **19**: 28–30.

Dangerfield BC and Roberts CA (1996). Relating a transmission model of AIDS spread to data: some international comparisons. In: Isham V and Medley G (eds). *Models for Infectious Human Diseases: Their Structure and Relation to Data*. Cambridge University Press, Cambridge, UK, pp 473–476.

Dangerfield BC and Roberts CA (1999). Optimisation as a statistical estimation tool: an example in estimating the AIDS treatment-free incubation period distribution. *System Dynamics Rev* **15**(3): 273–291.

Delesie L (1998). Bridging the gap between clinicians and health managers. *Eur J Opl Res* **105**(2): 248–256.

Dodds S (2005). Designing improved healthcare processes using discrete event simulation. *The British J Healthcare Comput Inform* **22**(5): 14–16.

DoH (2006). Press release: Hewitt announces action toturnaround NHS finances. Available at http://www.dh.gov.uk/PublicationsAndStatistics/PressReleases/PressReleasesNotices/fs/en?CONTENT_ID=4127292&chk=HDOR9C (accessed 23 February 2006).

Eldabi T, Irani Z and Paul RJ (2002). A proposed approach for modelling health-care systems for understanding. *J Mng Med* **16**(4): 170–187.

Eldabi T and Paul RJ (2001). Evaluation of tools for modelling manufacturing systems design with multiple levels of detail. *Int J Flexible Manufac Syst* **13**(2): 163–176.

Eldabi T, Paul RJ and Taylor SJE (2000). Simulating economic factors in adjuvant breast cancer treatment. *J Opl Res Soc* **51**(4): 465–475.

Eldabi T, Paul RJ, and Young TP (2004). *Position paper: simulation for the NHS*. Working paper, Brunel University.

Fone D *et al* (2003). Systematic review of the use and value of computer simulation modelling in population health and healthcare delivery. *J Public Health Med* **25**(4): 325–335.

Harper PR and Pitt M (2004). On the challenges of healthcare modelling and a proposed project life-cycle for successful implementation. *J Opl Res Soc* **55**(6): 657–661.

Huang J, Jennings NR and Fox J (1995). Agent-based approach to health care management. *Appl Artificial Intelligence* **9**(4): 401–420.

Jun JB, Jacobson SH and Swisher JR (1999). Applications of discrete event simulation in health care clinics: a survey. *J Opl Res Soc* **50**(2): 109–123.

Kuljis J, Paul RJ and Chen C (2001). Visualization and simulation: two sides of the same coin? *Simulation* **77**(3–4): 141–152.

Lagergren M (1998). What is the role and contribution of models to management and research in the health services? A view from Europe. *Eur J Opl Res (Internet)* **105**(2): 257–266, Available at http://www.sciencedirect.com (accessed 6 July 2003).

Lane DC (2000). *You just don't understand me: modes of failure and success in the discourse between system dynamics and discrete event simulation*. LSE paper, LSEOR 00.34.

Lane DC, Monefeldt C and Rosenhead JV (2000). Looking in the wrong place for healthcare improvements: a system dynamics study of an accident and emergency department. *J Opl Res Soc* **51**(5): 518–531.

Lattimer V *et al* (2004). Reviewing emergency care systems 1: insights from system dynamics modelling. *Emergency Med J* **21**: 685–691.

Lehaney B and Paul RJ (1996). The use of soft systems methodology in the development of a simulation of out-patient services at Watford general hospital. *J Opl Res Soc* **47**(7): 864–870.

Lehaney B, Clarke SA and Paul RJ (1999). A case of an intervention in an outpatients department. *J Opl Res Soc* **50**(9): 877–891.

MASHnet (2005). Modelling and simulation in healthcare. Available at www.mashnet.org.uk (accessed 17 February 2006).

Mea VD (2001). Agents acting and moving in healthcare scenario—A paradigm for telemedical collaboration. *IEEE Transac Inform Technol Biomed* **5**(1): 10–13.

NHS Institute for Innovation and Improvement (2005). Available at http://www.institute.nhs.uk/default.htm (accessed 15 September 2005).

NHS Modernisation Agency (2004a). 10 High Impact Changes for service improvement and delivery. Available at http://www.content.modern.nhs.uk-/cmsWISE/HIC/HIC+Intro.htm (accessed 12 October 2004).

NHS Modernisation Agency (2004b). Making see and treat work for patients and staff. Available at http://www.modern.nhs.uk/esc/8196/final%20See_&_Treat.pdf

NHS Modernisation Agency (2005). Available at http://www.wise.nhs.uk/cmswise/default.htm (accessed 27 August 2005).

Page EH *et al* (2000). Web-based simulation: revolution or evolution? *ACM Transac Model Comput Simulation* **10**(1): 3–17.

Pitt M (1997). A generalised simulation system to support strategic resource planning in healthcare. In: *Proceedings of the 1997 Winter Simulation Conference*, 7–10 December. Available at http://www.informs-cs.org/wsc97papers/prog97.html (accessed 5 July 2003).

Rawlins MD and Littlejohns P (2004). *Delivering Quality in the NHS 2004*. Radcliffe Publishing: Oxford.

Ridge JC, Jones SK, Nielsen MS and Shahani AK (1998). Capacity planning for intensive care units. *Eur J Opl Res* **105**(2): 346–355.

Rodgers GJ, Yap YJ and Young TP (2003). Simple models of waiting lists. *Adv Complex Syst* **6**(2): 215–222.

Royston G (1999). Commentary: trials versus models in appraising screening programmes. *BMJ* **318**: 360–361.

Royston G (2005). Modelling and simulation in health—potential, achievement and challenge. *Presentation for MASHnet launch*, September 2005. Available at http://www.pms.ac.uk/mash

net/index.php?section=sub&act=MASHnetLaunchReport20Sep05#RoystonTalk (accessed 17 February 2006).

Royston G, Dost A, Townshend J and Turner H (1999). Using system dynamics to help develop and implement policies and programmes in health care in England. *Syst Dynamics Rev* **15**(3): 293–313.

Sanchez SM, Ferrin DM, Ogazon T and Sepúlveda JA (2000). Emerging issues in healthcare simulation. In: *Proceedings of the 2000 Winter Simulation Conference*. Available at http://www.informs-cs.org/wsc00papers/prog00.htm (accessed 1 July 2003).

Standridge CR (1999). A tutorial on simulation in healthcare: applications and issues. In: *Proceedings of the 1999 Winter Simulation Conference*, 5–8 December. Available at http://www.informs-cs.cs.org/wsc99papers/prog99.html (accessed 1 July 2003).

Wilson JCT (1981). Implementation of computer simulation projects in health care. *J Opl Res Soc* **32**(9): 825–832.

Young TP *et al* (2004). Using industrial processes to improve patient care. *BMJ* **328**: 162–164.

Received October 2005;
accepted March 2006 after two revisions