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MIXING OTHER METHODS WITH SIMULATION IS NO BIG DEAL

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ABSTRACT

It is clear that methods are mixed in practice. Problems don't come labelled as simulation, optimisation, forecasting, or with some other methodological name. In practice, there's a job to be done and the analyst must find a way to do it. For over 20 years, optimisation within discrete simulations has been a fertile field of research. Employing time series methods to analyse simulation output and to model input data is routine. Thus, in one sense, we should not be too exercised by the very idea that methods are usefully mixed in research either. Climbing to a higher level, it is likely to be rare that major decisions are made solely on the basis of a few simulation runs. A model is likely to be one element of a decision making process that leads people to see that a particular course of action is either desirable, or less undesirable than alternatives.

1 INTRODUCTION

This stream within the Healthcare Track at WSC12 carries the title 'Combined Application of OR/Simulation Techniques for Better Decision Making in Healthcare'. This might suggest that combining methods is unusual or, possibly, should only be attempted by people wearing protective clothing after an appropriate risk assessment. However, I wish to take a very different line in my contribution to the stream. That is, I wish to argue that combining other methods with discrete event simulation (which is the main focus of WSC12) should be the norm. I attempt a brief examination of the evidence about whether this is indeed the case. I do this as someone who has been part of OR/MS groups for many years, rather than a mathematician or statistician. Because of this, my approach may be rather more pragmatic than that favoured by others.

1.1 Modelling and Simulation 101

As ever, we need to start with some definitions in order to bring some conceptual clarity to the discussion. First, what do we mean by simulation? I was first forced to think about this when I was given the task of teaching an undergraduate class on simulation in my earliest academic post. At the time, as was common in the UK, I had no PhD and so had never been forced to think in the conceptually clear terms that characterise a good doctoral dissertation. Also, though I'd been taught a simulation course whilst a Masters student, I could not recall any attempt to define what we were up to; it was simply taken for granted. Since I was employed to teach in an OR & Systems group, I dug out my (even then) ancient copy of Ackoff and Sasieni (1968) where I read (p97, with the original italics) 'Models *represent* reality, simulation *imitates* it. Simulation always involves the manipulation of a model; it is, in effect, a way of manipulating a model so that it yields a motion picture of reality'.

Thus, simulation appears to be the use of a model to mimic how a real system of interest might behave, and presumably the model has been constructed with that end in view. The mention of a motion picture suggests that the imitation will be dynamic; that is, we are concerned with a model that changes state through time. This is important, since the dynamic interactions in a discrete event simulation are

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usually the causes of any interesting or emergent behaviour, and typically also lead to some of the problems that we face when analysing the output from one or more simulation runs.

Many years later I produced my own definition of a model as 'an external and explicit representation of part of reality as seen by the people who wish to use that model to understand, to change, to manage and to control that part of reality.' (Pidd 2009, p10) This definition is based on my own assumption that modelling in OR/MS is a purposeful activity and not just a leisurely pursuit followed by gentlemen and ladies of independent means. Note, too, that this definition of a model can be used in many, if not all technical areas or OR/MS, including optimisation, forecasting, stochastic processes, routeing and gaming. This generality is deliberate, since problems do not come labelled as simulation, optimisation, forecasting, or with some other methodological name. In practice, there's a job to be done and the analyst must find a way to do it.

2 WHAT ARE THE OPTIONS FOR MIXING METHODS?

The above introduction raises the question of how we go about doing whatever it is that we do.

2.1 Discrete Event Simulation and Other Approaches

My own field of OR/MS includes a very wide range of methods and techniques, some of which were developed within it, whereas others were adopted from elsewhere. There are many different ways of classifying them and here I make a distinction between three categories:

1. Mathematical models: These cover a wide spectrum that ranges from evaluative models at one end, and optimisation models at the other. Within OR/MS, evaluative models are computation devices that are intended to allow users to explore the consequences of particular actions, options or system configurations. These range from simple spreadsheet models to highly complex mathematical representations of a system of interest. At the opposite end of the spectrum are optimisation models that algorithmically explore a solution space to determine an option that best satisfies some clearly expressed objective function.
2. Logical models: This is a category that includes most discrete event simulations. Though we can obviously treat logic as a branch of mathematics, there is a distinct difference between models that are intended to explore situational logic by focusing on interactions between agents, objects and entities and mathematical models that are algorithmically programmed, computational devices.
3. Interpretive models: These are developed through approaches that are often described as 'soft OR', and can include root definitions and activity models in soft systems methodology, causal maps and some uses of Bayesian decision theory and system dynamics.

The question of whether discrete event simulation methods should be mixed with other approaches is thus seen as a specific case of a more general question about mixing methods across these three categories.

The particular type of logical representation that underpins a discrete event simulation has several well-known characteristics (Pidd 2004). The term 'discrete' carries with it two requirements; first that our main focus is a set of discrete (individual) entities and, secondly, that these entities inhabit discrete and disjoint states. An event connotes the points in time at which such entities change state, which leads to a focus on the rules that govern such state changes. Thus, as attendees at this conference know, discrete event simulations are also dynamic and it is this ability to mimic dynamic behaviour that is one of the most powerful aspects of discrete event simulation.

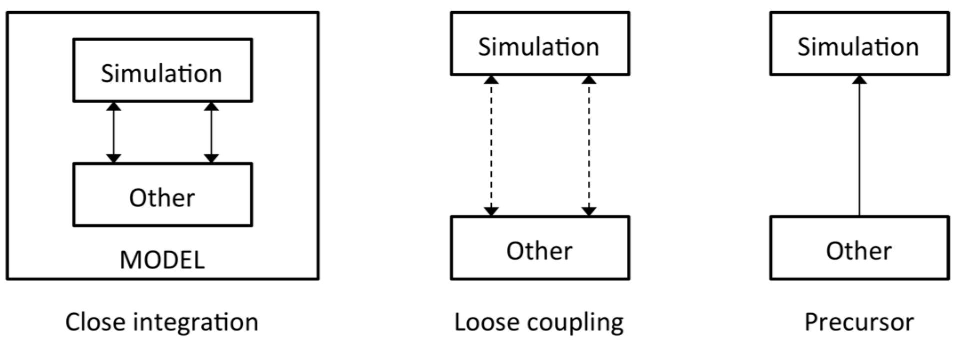
In addition to a concern with such discrete events and their occurrence through simulated time, most discrete event simulations also mimic stochastic behaviour, which is usually achieved through some form of (controlled) random sampling. To an outsider, this stochastic representation appears to produce non-deterministic behaviour, however the use of random number generators means that this is an illusion.

2.2 An Initial Hypothesis

It seems sensible to distinguish between different approaches to mixing methods. One way to do this is to consider three approaches as shown in Figure 1.

1. The close integration of different approaches within a single model: examples of this might be a discrete event simulation embedded within an optimisation or vice versa. Thus the simulation generates values for the optimisation, or vice versa, and the two adapt to one another. The routine provision of heuristic optimisation within simulation software packages (REFS) is one example of this approach. In the terms introduced above, this is the close integration of a logical model with a mathematical one.
2. The loose coupling of different approaches: examples might be situations in which a simulation model runs separately from another approach (e.g. system dynamics or a Bayesian model) and the two periodically communicate and exchange data. This loose coupling could involve either an interpretive or mathematical model being used alongside a logical model
3. The use of one approach as a precursor to the other: this is particularly common in the use of interpretive models as conceptualisation devices prior to the development of a logical model in the form of a discrete event simulation. (Pidd 2007; Kotiadis and Mingers 2006), or a system dynamics model.

Figure 1: Approaches to mixing methods



In addition, of course, many published accounts of simulation modelling do not involve its explicit combination with other approaches, and we can label these as *approach 0*. This then leaves us with the opportunity to examine how common the four approaches are in practice. Sadly, we do not have access to anything like a full set of reports of simulation practice and so must resort to the published literature, which mainly focuses on research.

3 WHAT DOES THE RESEARCH LITERATURE TELL US?

There is no perfect way to access and summarise the research literature on any topic, for the purposes of this paper, the search facilities of the *International Abstracts in Operations Research* (IAOR) were used to find relevant papers, based on the following search terms:

- Years: 1983 – 2011
- simulation AND (healthcare OR hospital OR clinic OR physician OR doctor OR nurse)

This search produced 192 hits across the diverse set of journals covered by IAOR, which were examined to see how common it is to describe combined use of other methods with computer simulation. There are many reviews of the use of simulation in healthcare, but that is not the purpose of this paper, which focuses on the combined use of simulation and other approaches in healthcare.

In all cases, the abstracts were read and, in some cases the full papers were also read. Since IAOR is a service based on the abstracts written by the authors of the papers, it would be strange to include any in this survey with abstracts that did not mention any of the terms in the above search expression. If the authors omitted those terms from their abstract, it seems sensible to assume that the ideas themselves did not play a major role in the paper and that there was no reason to read the full paper.

Thus, the papers selected are highly likely to be the full set of those that use the ideas within their main text. It might however, as noted below in section 3.2, have been useful to extend the search to substitute 'health' instead of 'healthcare' – though this might also have captured quite a few spurious hits in its net.

3.1 Papers Included and Excluded

Of the 192 papers returned by the IAOR search, 23 were excluded for two reasons. The first is that the abstract contained no clear link to healthcare, or because there was no mention of simulation in it. These papers should not have been captured by the search, but were; presumably due to a quirk in the search engine. Secondly, the IAOR database contains a few duplicate entries, which were also excluded. This left 169 papers across the nearly 30 year period- which seems surprisingly small.

3.2 Journals Covered

The 169 papers were published in 44 different journals, which indicates either a widespread interest n healthcare simulation modelling, or that no single journal predominates. Table 1 analyses the publication pattern by journal. Most of the 44 journals published very few relevant papers over the period and all that published fewer than 5 are included in the remainder line of Table 1.

It should be noted that the figures in Table 1 are biased by the number of papers published in each journal over the period 1983 to 2011. Over that period, the European Journal of Operational Research has published many more papers than the rest on all subjects relevant to its mission. The Journal of Simulation only published its first volume in 2007, but has 9% of the papers included in the analysis. OR Insight is a practitioner-targeted journal produced by the UK Operational Research Society and publishes short, practitioner-oriented pieces that contain very little technical detail.

Table 1: Analysis of Journals

Journal	Papers	%
Euro Jnl Opl Res	13	8
Health Care Management Science	36	21
Journal of Simulation	15	9
Jnl Opl Res Soc	33	20
OR Insight	9	5
Prod & Ops Mgt	8	5
Remainder	55	33
TOTAL	169	100

It is perhaps significant that no INFORMS journal appears in this analysis. There are several possible reasons for this, one of which may be that other search terms may be appropriate as different keywords are used in some journals. Chick (2012) reports that a quick search of the INFORMS PubsOnline database using 'health and simulation' as a search term produces 125 articles for the same period, but that a significant number seem to be overviews rather than exemplars or theoretical developments.

The IAOR search also included a very small number of papers published in medical journals, such as the British Medical Journal. This small number is also troubling, but may be a function of the journals covered by IAOR.

3.3 Approaches Adopted

Though section 2.2 proposed a 4-way classification, examination of the 169 papers included in the analysis showed that a somewhat broader view was needed, and six categories were needed to capture the range of approaches, since category 3 needed to be split to reflect the inclusion of some papers in which a hypothetical simulation models was a convenient device to allow researchers to demonstrate the possible value of the other approaches that they propose (e.g. methods for nurse scheduling). The revised set of categories is shown in Table 2, together with an analysis of the papers.

It is clear that most of the papers found by the IAOR search, report relatively straightforward accounts of the development and use of a simulation model intended to provide benefits in healthcare. Only 4% report close integration of simulation and another approach within a single model. Given the efforts made in the manufacturing sector to use simulation methods as part of scheduling procedures, this may seem surprising to those unfamiliar with the types of variation present in many healthcare settings. There were also very few examples of the explicit use of other approaches as direct precursors to the development and use of a simulation model. Most common was loose coupling; that is, the use of a simulation model in conjunction with other approaches, with the simulation model feeding off the other approach and vice-versa.

Table 2: Revised set of categories and consequent analysis

	Category	**Description**	**Papers**	**%**
0:	Only simulation	No mention of any link to other methods and approaches.	91	54
1:	Close integration	Development and/or use of a single model or application in which simulation and another approach are closely integrated.	7	4
2:	Loose coupling	In which a simulation model was employed alongside another approach, such as a queuing model or a separate optimiser.	34	20
3a:	Active precursor	Use of another method as an active precursor to a simulation.	6	4
3b:	Simulation for evaluation	In which a simulation model is used to produce the semi-realistic evaluation of policies developed separately	20	12
4:	Survey	Survey paper or comparison of several methods for a problem area	11	7
		TOTALS	169	100

4 DISCUSSION

The headline story from this analysis could either be: *Most healthcare simulation papers don't link to other methods and approaches*, or: *About 40% of healthcare simulation papers report the use of simulation together with another approach*. Which headline is deemed appropriate may depend on the case that is being argued. That is, the jury is still out.

We can, though, dig a little data even into such a sparse data set. For example, we can assess whether the position has changed through time. Examination of the papers found by the IAOR search shows very few before 1990. To assess whether the position has changed since 1990, we can divide the papers into those produced in the 20th Century and those produce since the turn of the Millennium. The results of this analysis, using the six categories of Table 2, are shown in Table 3.

Table 3: Comparison on 1983-1999 with 2000-2011

	Category	**1983-1999**		**2000-2011**	
		Papers	**%**	**Papers**	**%**
0:	Only simulation	26	100	65	45
1:	Close integration	0	0	7	5
2:	Loose coupling	0	0	34	24
3a:	Active precursor	0	0	6	4
3b:	Simulation for evaluation	0	0	20	14

4:	Survey	0	0	11	8
	TOTALS	26	100	143	100

Two things are obvious from this comparison. The first is that many more papers per year have been published since the year 2000 than in the longer period from 1983. This is partly because new journals have appeared this century and also because some journals have grown larger. However it also seems to reflect the increased healthcare simulation activity that is evident in the programmes of the Winter Simulation Conference over the same periods.

The second is that the percentage of papers in categories 1, 2, 3a and 3b, which describe work in which simulation approaches are combined with other methods has increased from zero to 47% and therefore outnumbers the papers of papers that discuss an approach in which only simulation was used. If we remove the papers in category 5 (surveys and think pieces), the proportion devoted to linking simulation with other approaches rises to just over 50%.

Hence, it seems fair to conclude that, even in the research literature, the number of papers that discuss the combined use of simulation with other approaches in attempts to improve healthcare has greatly risen since the turn of the Century. Whether the same applies to practitioner work remains to be explored. These conclusions, of course, apply only to simulation methods in OR/MS as applied to healthcare and may not apply in other domains. However, it would be interesting to compare the popularity of such combination in healthcare with other areas such as manufacturing and logistics.

It is also possible, as mentioned in section 3, that a search with a more extensive set of terms would through up more hits; if so, it would useful to know whether a similar pattern emerges.

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