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Cross-sector analysis of simulation methods: a survey of defense and healthcare

Aisha Naseer and Tillal Eldabi
Brunel Business School, Brunel University, Uxbridge, UK, and
Mohsen Jahangirian
School of Information Systems, Computing and Mathematics, Brunel University, Uxbridge, UK

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Abstract

Purpose – The purpose of this paper is to see whether it is possible to learn any lessons from the application of simulation and modeling in the defense sector to be applied in the healthcare sector.

Design/methodology/approach – Two comprehensive reviews are conducted within two domains of "Military & Aerospace" and "Healthcare". A general search framework with common features is developed, while allowing rooms for customization for each domain. A common objective is set to cover a wide scope of simulation methods and application areas. Further, reviews are not restricted to a limited number of journals or conferences; rather the relevant databases are searched while using some filtering mechanisms.

Findings – It is found that simulation has been commonly used in the defense sector(s). However, inconsistency in terms of the level of implementation in both the sectors is quite vivid. There is clear evidence that healthcare lags behind other sector(s), particularly in terms of stakeholder engagement and, consequently, in terms of implementation of simulation outcomes.

Research limitations/implications – Owing to confidential nature of the defense sector, grey literature (which in this case is likely to include a considerable corpus of classified material) has not yet been reviewed. The paper speculates on the impact this has on the appreciation of the uptake of modelling and simulation in this sector and could form part of future research.

Originality/value – This paper provides key insights into some challenges of applying simulation methods in healthcare, whilst presenting an up-to-date overall picture of simulation in two main sectors from an academic point of view.

Keywords Aerospace industry, Armed forces, Simulation, Modelling, Surveys

Paper type Literature review

1. Introduction

It is a well known fact that simulation modeling is widely used in the defense sector, with high levels of imbedded-ness and routine-ness, representing a vital part of any planned project for both sectors. The story is, however, slightly different in healthcare, as simulation, although widely applied (Fone *et al.*, 2003) for the past 30 years, is yet to

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become an essential part of the decision making process. It is not clear why simulation has not become as integral to the actual decision making process rather than merely a data categorization tool.

Young *et al.* (2004) and Kuljis *et al.* (2007) amongst many others have stressed and asserted the need to learn from other industries to enhance the benefits of simulation in healthcare. The question that poses itself here is that: if simulation has been known in the field of healthcare for more than three decades, why is it still struggling to make an impact same as in Military & Aerospace. To identify the lessons that can be learned from the other sector(s) and transferred to healthcare domain, the authors suggest that it is essential to profile and identify the similarities and differences in the application of simulation within the two sectors. Hence, the aim of this paper is to conduct a cross-sectional analysis of two major reviews of the academic literature for each sector, respectively.

Multiple reviews were conducted as part of a research project – the research into global healthcare tools project (RIGHT) (www.right.org.uk for more details) – that aims at mapping and connecting up modeling and simulation tools in order to subsequently develop a systematic way of selecting the best tool that fit the problem and the stakeholders. The ultimate output of the project is a framework toolkit that would enable users to assess their scenarios and resources in accordance to the available (modeling and simulation) methods in order to select an appropriate method, which would best suit their needs. The first phase of the project is to conduct extensive literature reviews about the use of simulation and other management practices within and beyond healthcare domain to identify a set of lessons that can be learned for developing the toolkit.

This paper is an extension of the work presented about the potential applications of Modeling and Simulation methods in healthcare (Naseer *et al.*, 2008) and reports on two of the RIGHT reviews and performs cross-sector analysis between Military & Aerospace, and healthcare in order to identify which lessons can be learned from the former into the later, respectively. The paper is structured as follows: introduction, previous work, literature review methodology, results and analysis, and finally conclusions at the end.

2. Previous work

There are very few previously published articles that perform cross-sector analysis of simulation projects. Even though, a number of reviews exist for each of the two sectors. For example, Jun *et al.* (1999), Fone *et al.* (2003) for healthcare; and Coolahan (2005), Hu and Sun (1999) for Military & Aerospace. A recurrent theme in these and many other reviews is that they present detailed accounts of their respective sectors, however, not much comparison or reference to other sectors is given. Another review by Grenvik *et al.* (2004) describes the use of simulation in healthcare as compared to the Military & Aerospace sector; and the advantages of simulation training over traditional medical education methods were identified. However, the reviews were not comprehensive enough and some examples of the unique challenges of simulation modeling in healthcare were given.

It must be noted that a number of articles provided useful expert opinions about the cross-sector evaluation of simulation projects and mutual lessons. For example, Pidd and Robinson (2007) provide a set of hypotheses regarding the different modes of simulation practice in business and military sectors. They suggested, using expert opinion, that most models in military are large-scale and long lasting, which means

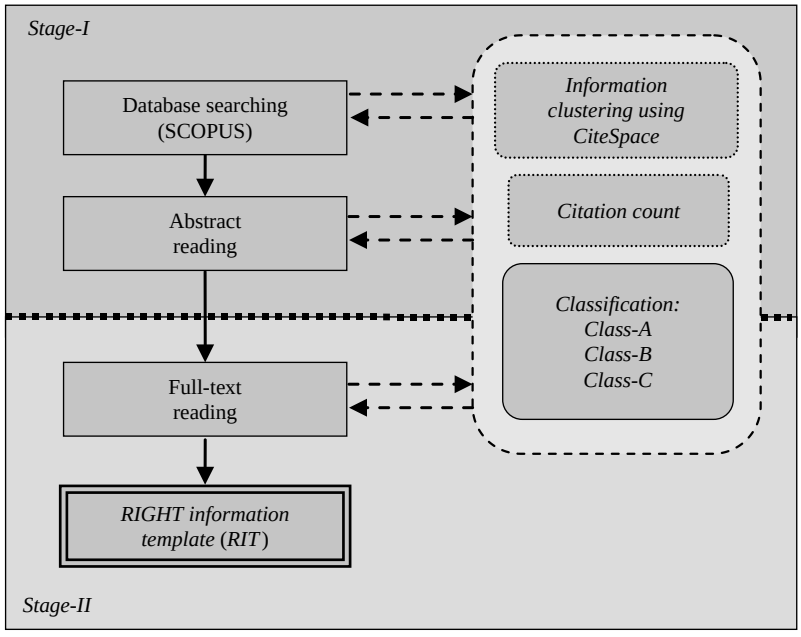
cost and time duration of modeling is not an issue. Whilst in manufacturing and business, cost and time are more important. This indicates that the nature of the domain dictates the way simulation is approached. A useful discussion on this is given by Young *et al.* (2004) that simulation methods may be identified for modeling healthcare problems from other mainstream application domains, such as manufacturing and military. On the other hand, Banks (2001) discussed the future of simulation in various sectors including manufacturing, healthcare, construction, consulting, logistics and military. However, no conjoint or cross-sector analysis was performed as to how each of these sectors can benefit from the other.

Most of these views lack evidence from industry and academia that support such claims. This paper attempt to provide some evidence to the above claims and test some of the preconceived hypothesis about the relationship between the two sectors. The following section presents a brief description about the methodology followed for collecting information about the two sectors from the academic literature.

3. Methodology

Two comprehensive reviews were conducted within two domains, i.e. Military & Aerospace, and Healthcare. A general search framework with common features was developed, while allowing rooms for customization for each domain. A common objective was set to cover a wide scope of simulation methods and application areas. Further, we did not restrict our reviews to a limited number of journals or conferences; rather, we opted to search in the relevant databases while using some filtering mechanisms.

The literature review for the field of Military & Aerospace was a two-stage process, as depicted in Figure 1 (Naseer *et al.*, 2008). This review covered academic,



Source: Naseer *et al.* (2008)

Figure 1.
The literature review framework

peer-reviewed publications on the applications of simulation in the field of Military & Aerospace over the past 10-years (1997-2006). Scopus database (SCOPUS, 2008), which is arguably the largest citation database covering the most relevant articles to the domains addressed, was searched to identify the initial batch of academic papers. The search was conducted with the Boolean keyword combination "(simulat* OR 'system dynamics') AND (aerospace OR military)".

Through the two-stage search methodology, we managed to narrow down the search space from a total of around 19,700 to 482 papers for both sectors (Table I) using a varied set of tools and mechanisms such as CiteSpace clustering tool (Chen, 2006), Scopus filtering tools as well as a filtering mechanism based on two criteria, i.e. citation count and random sampling (see Eldabi *et al.*, 2008 for more details on the methodology). These features enabled us to handle the huge corpuses of literature in an effective and efficient way.

The second review of healthcare simulation studies utilized a hierarchical system of classification, introduced for various methods and functional area of applications. We considered the mainstream literature, accessible through three of the most widely used academic electronic databases: JSTOR (2008), SCOPUS, and ISI Web of Knowledge (WoK, 2008). JSTOR and SCOPUS both provide "relevance" ratings and these were used to rank the first 500 papers in both databases for abstract scanning. It was not possible to discover the algorithm used to determine this relevance rating, but it was clearly based on the frequency of occurrence of the search terms. Many papers were eliminated at this stage, for example as they were found to be book reviews, abstracts of conference presentations, or were about cost-effectiveness analyses of drug treatments. WoK did not provide such a ranking and therefore CiteSpace was used to produce a list of 60 key papers (the process is described in Brailsford *et al.*, 2008). Duplicates were also removed, which were not many.

The healthcare literature review consisted of three stages. First, the selection of literature with a broader query criteria. Second, the selection of samples for full-text and abstract review. Third, verification of the selected publication's suitability and review with full-text. The filtering mechanisms that were used in the Military & Aerospace review were also adopted in the Healthcare review. Both reviews also used reference chasing methods (both forward and backward) to identify the key papers and the emerging issues. Thus, our methodology has more in common with stratified experimental sampling than the kind of exhaustive survey typically attempted in a conventional literature review.

In order to consolidate and analyze the results in a more standardized way, two categorization schemes criteria were used level of stakeholder engagement, and simulation application areas. The first criterion addresses the challenges of implementations and the user engagement in simulation projects. This enabled us to classify the literature into three groups:

Number of papers	Military & Aerospace	Healthcare
Total	~10,000	~9,700
Abstract	900	1540
Full-text	300	370
Final	140	342

Table I.
Number of papers

(1) *Class A or real problem-solving articles.* Simulation has been applied in the project where real problem with real stakeholders were used. This class demonstrates a project with the highest amount of user engagement in the simulation part.

(2) *Class B or hypothetical problem-solving articles.* Simulation has been applied to solve a real-life problem, but using artificial data rather than real data and not much engagement with actual stakeholders.

(3) *Class C or methodological articles.* Simulation is only being considered as a potential tool to solve a problem. No experimental study is carried out. This class demonstrates a project with the least amount of user engagement in the simulation part.

We also defined a structure for classifying selected publications from applications point of view. This structure comprised a fixed list of the eight categories shown in Table II (Brailsford *et al.*, 2008). The scheme reflects the mainstream functional areas of the healthcare, whilst focusing on the management and process-oriented fields.

4. Results and analysis

Having captured the information from the two reviews, we analyzed the results from a number of perspectives: the level of stakeholder engagement, popularity of simulation method per application area, and prevalence of modeling per each sub-application area. The following subsections provide detailed account for each of these perspectives coupled with lessons learned in support of healthcare from other disciplines.

4.1 Level of stakeholder engagement

Simulation was found to be most commonly used in strategic planning (Prasithsangaree *et al.*, 2004) and simulated battlefield trainings (Ebbutt, 2005) and (Oliver, 2005). Nonetheless, there has always been a concern over the stakeholder engagement of the simulation projects. Comparative results from stakeholders engagement perspective, as depicted in Figure 2 clearly shows how healthcare is lagging far behind the other sector(s). Assuming that implementation is a direct consequence of stakeholder engagement, it is clear that simulation is not leaving much impact on decision making within healthcare despite the high level of awareness which is indicted earlier.

Area code	Healthcare application area	Appropriate simulation methods
Policy	Finance, policy, governance, regulation	SD and ABS
Strategy	Public health, community service planning	DES and SD
Training	Workforce/staff management	DES
Operations	Planning, system/resource utilization	DES
Evaluation	Quality management, performance monitoring and review	DES
Research	Research and development	SD and DES
Risk	Risk management, forecasting	Monte-Carlo
Behavior	Patient behavior/characteristics	ABS and Monte-Carlo

Table II.
The appropriateness of simulation methods for various application areas

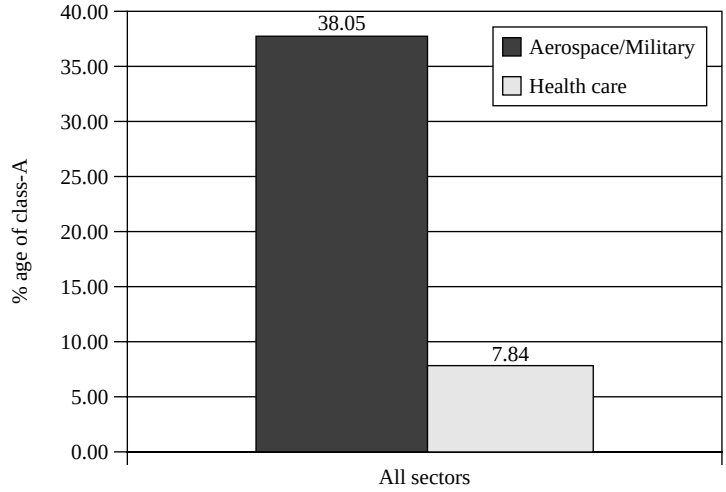


Figure 2.
The percentage of stakeholders engagement within each sector

4.2 Popularity of modeling per application area

Figure 3 shows the distribution of usage of modeling – in general – amongst the different sub-application areas for each of the two sectors. It is quite evident that the use of modeling is mainly prevalent at the operational level and takes a major share within the Healthcare domain. It can be seen from Figure 3 that military uses invest a large amount of the modeling effort on training which is much higher than that of healthcare. It can also be seen that Healthcare sector invest more effort on research and evaluation of services, which may have some implication on findings from previous section. The reader is reminded that the eight sub-application areas have been identified based on results from the literature search and previous categorization.

4.3 Popularity of methods used

When comparing the Military & Aerospace sector with Healthcare, it is evident from Figure 4 that DES is the most widely used method in Healthcare, with comparatively

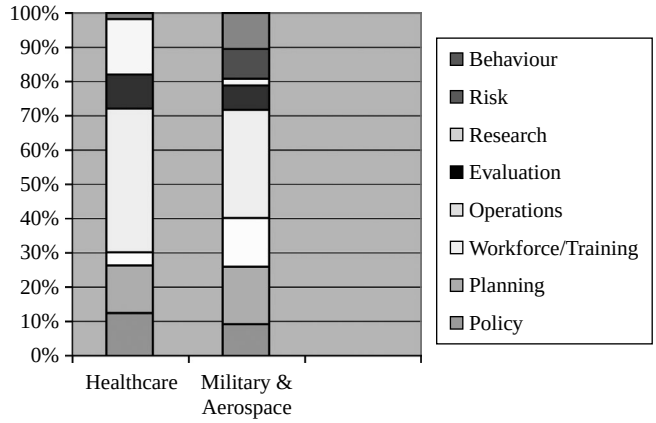


Figure 3.
Popularity of modeling and simulation per sub-area

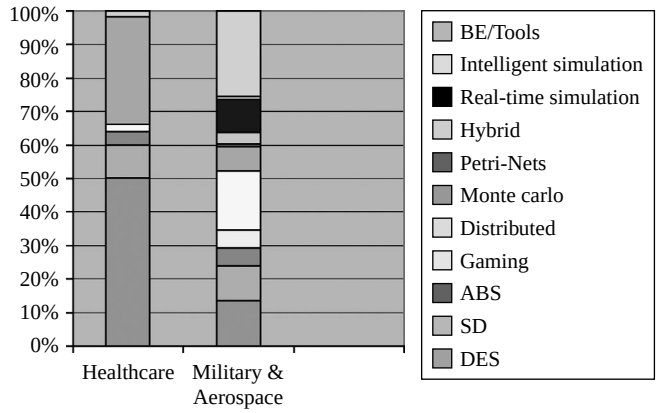


Figure 4.
Simulation methods per domain

lesser application in Military & Aerospace. However, distributed simulation has been the most widely adopted method in Military & Aerospace. Moreover, it is found that most of the military uses bespoke tools for the specific context being modeled. Monte Carlo is another widely used method in healthcare when compared with the other sectors; however, it is not clear why this is the case from this review.

4.4 Application-simulation method mapping

Table II summarizes findings from Figures 3 and 4. It can be concluded that DES has been dominant for tactical and operational decision-making levels. Whilst system dynamics (SD) is particularly suitable for policy/strategy levels as well as conceptual and qualitative analyses such as in R&D. Agent based simulation (ABS) looks more promising in the area of behavioral studies and somehow in policy/strategy. Finally, Monte-Carlo Simulation has its own competence in risk/financial areas where probabilities and numerical calculations play a major role. It appears that healthcare sector has realized the dominant method only for one application area, i.e. planning, system/resource utilization. Therefore, the current survey could provide some knowledge about application-simulation method mapping to be transferred from Military & Aerospace sectors to the Healthcare sector.

5. Conclusion

This paper attempted to profile two main sectors (namely Military & Aerospace, and Healthcare) in terms of their utilization of simulation as a precursor for identifying lessons to be learned and transferred to the Healthcare sector from the other sector(s). The results of two comprehensive reviews conducted in this research provide insights into the roles and capabilities of simulation methods. Two series of analyses were carried out. First, the comparative results claim that Healthcare lags far behind the other sector(s) in terms of the stakeholder engagement. Such lack of stakeholders' engagement has left a negative impact on the level of utilization from the model, in addition to reduced implementation of findings and general lack of appreciation of the role of simulation in healthcare. Below, a number of discussion points why there is not much engagement from Healthcare stakeholders:

- *Organizational structure.* Healthcare systems usually have no specific owners (as there are many of them). This reduces the sense of sole ownership and, hence, reduces the need and inclination to engage in long and drawn problem solving exercises. Contrary to that we find military structures are more rigid.
- *Competitive behavior.* There is a significant difference between the Military & Aerospace and the Healthcare environments, in terms of level of competition. These two factors have direct impact on measures of performances and the decision makers' motivation. Such phenomena signifies the need for success and, hence, the importance of modeling.
- *Training culture.* Military & Aerospace systems seem to have a well founded training culture. This has always been one of the main uses of simulation in this sector. Healthcare has training elements on the clinical side – which uses simulation a lot – but such culture is not as imbedded when looking at system management levels. See Figure 3 for "training" proportion.
- *Data capture.* There are usually high restrictions on usages of data in the healthcare sector that imposes a great challenge for information-intensive techniques such as simulation. This usually repel stakeholders from engaging in such modeling exercises.

The research is just beginning and there are so many aspects to investigate, including the above points beside some of the weaknesses of this research, for example, this review is only based on academic literature which tells only one part of the story, as there are many realistic examples available within the non-academic literature that need to be reviewed. Yet we hope this profile represents a valid starting point for identifying the means of addressing current challenges in the area.

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Corresponding author
Aisha Naseer can be contacted at: aisha.naseer@brunel.ac.uk