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A Survey of Simulation Research in Information Systems Discipline

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Abstract

Simulation is a research method that abstracts real-world phenomena into laboratory experiments, through computational modeling. Despite its widespread adoption in natural sciences, simulation is less prevalent in social sciences, and rare in Information Systems (IS). To facilitate IS simulation research, this study conducts a literature review through content analysis, focusing on the use of simulation methods in IS. Coding schemes are developed to characterize literature from the AIS basket-of-eight plus *Information & Management*. Results demonstrate the adoption of simulation method is limited in IS, in amount, geographic range, topic-spread, and techniques employed. At the same time, findings too suggest strong simulation research into certain topics and in multilevel theorizing.

Keywords content analysis, literature review, simulation, computational modelling, methodology, Information Systems research

1 Introduction

Simulation is a research method that seeks to imitate real world processes in a virtual world. This method is able to structurally analyse multiple interdependent processes operating simultaneously, which cannot be done through traditional approaches (Harrison et al. 2007). The research community has identified several strengths of simulation method: clarity, ease of comparability, logical power (Harrison et al. 2007), and tractability of computational models (Anderson 1999). Despite these strengths, the impact of simulation research remains relatively low in social science disciplines (Davis et al. 2007; Harrison et al. 2007), being especially rare in IS (Zhang and Gable 2014).

One possible reason for the dearth of simulation research in IS, is "a lack of clarity about the method and its related link to theory development" (Davis et al. 2007, p. 480). In attention to this issue, several authors have sought to clarify the rationale of simulation method (e.g. Anderson 1999; Anderson et al. 1999; Burton and Obel 2011; Harrison et al. 2007) and present prescriptive guidelines (e.g. Davis et al. 2007). A further reason suggested for the lack of take-up is the poor "value construction" reported in simulation research (Zhang and Gable 2014). With the aim of growing the IS simulation research community, Zhang and Gable (2014) develop a framework describing various contributions possible from simulation research, and offer advice to researchers for clarifying and maximizing their value argument. The discussions of the two streams are valuable, but they lack evidentiary bases. Grounded works are needed to substantiate the discussions. Another possible reason for the less adoption is that simulation research in IS lacks identity. By identity, we refer to the knowledge of the specific strengths and shortcomings of simulation method in the IS context, when compared to other conventional but more prevalent methods such as case study and survey. Such knowledge can assist IS researchers to make wiser choices when deciding to employ simulation method.

Addressing the mentioned issues above, this research is intending to examine IS simulation studies to understand how simulation method has been actually used in IS. In specific, the study undertakes a structured literature review of IS simulation research, using content analysis. Through this approach, this research can provide concrete evidences of low adoption, locate the specific methodological gaps, and increase identity of simulation method for IS context. For type of information being surveyed, we build on prior works. The method of profiling existing research has been long employed to explore intellectual cores of IS discipline to promote IS research. Previous literature in this vein has reported information of author prominence, research impact, research topics, research methods, single level of analysis, and research approaches (e.g. Palvia et al. 2007; Vessey and V Ramesh 2002). Beyond these earlier works, we also investigate several other aspects of simulation research, including multiple level of analysis use, and simulation validation techniques.

The rest of this paper is structured as follows. Given space constraints, we do not include a separate literature review section, but rather sparingly cite relevant literature throughout the document. In the next section, the research design is introduced; content analysis and coding schemes are discussed. Then, coding outcomes are reported and analysed. Subsequently, study findings are discussed, and discussion and limitations are presented. Finally, research conclusions are described.

2 Research Design

This research adopts a content analysis approach for literature review. Content Analysis is "a research technique in which ideas, meaning, and expression in a text are studied through analysing patterns in elements of the text, such as words or phrases" (Yang and Miller 2007, p. 689). To ensure rigor, content analysis method requires careful design of coding schemes in advance (Weber 1990). A coding scheme is a pre-defined classification system with necessary details to determine a code for the source texts, in a repeatable manner.

Next, the literature search strategy and the coding schemes are introduced.

2.1 Literature search strategy

Due to feasibility, journals selected for search are the AIS Senior Scholars' Basket-of-eight Journals, namely: *MIS Quarterly (MISQ), Information Systems Research (ISR), Journal of Management Information Systems (JMIS), European Journal of Information Systems (EJIS), Information Systems Journal (ISJ), Journal of the Association for Information Systems (JAIS), Journal of Information Technology (JIT), and Journal of Strategic Information Systems (JSIS)*. In addition, we also include *Information & Management (I&M)* for its high reputation in our community. Although the nine journals cannot cover all simulation studies in the IS discipline, they generally include simulation research with the highest quality. The employment of simulation method in high quality researches should largely represent the adoption of the method in IS discipline.

Our search script to identify simulation research, following, derives from two prior studies that searched the IS simulation literature (Spagnoletti et al. 2013; Zhang and Gable 2014).

> *"simulation" OR "computational model*" OR "computer model*" OR "agent-based" OR "multi-agent" OR "system dynamic*" OR "NK fitness landscape" OR "genetic algorithm*" OR "cellular automat*" OR "stochastic process"*

The initial search yielded 143 papers. The type of literature is coded as: 1) Computational simulation – simulation research with the definition of computational modelling; 2) Comment –research focusing on methodology comments; 3) Economic/mathematical modelling – research in which the main focus is developing complex mathematical models and simulation is generally used to generate data, mostly for a validation purpose; 4) Framework developing – research intending to develop analytic frameworks for specific scenarios using simulation; 5) Human experimentation – research designing human experiments to simulate real contexts; 6) Monte-Carlo simulation – research using Mote-Carlo method to generate input data for testing; 7) Systems simulation – research simulating a specific system instead of developing and validating social science theories; 8) Validation – simulation is simply used as a validation technique; 9) Other – other research not covered by previous categories; most studies in this categories have nothing to do with the simulation method. The distribution of the initial search outcomes is illustrated in table 1. Apparently, the IS research community has not achieved a consensus regarding what is simulation research. Considering simulation as computational modelling, we retained the 41 computational simulation researches for the backbone of this study.

Category	**Number of publications**	**Percentage**	**Category**	**Number of publications**	**Percentage**
Computational simulation	41	29%	Comment	10	7%
Other	30	21%	Framework developing	9	6%
Human experimentation	18	13%	Systems simulation	5	3%
Economic/mathematical modelling	13	9%	Validation	5	3%
Monte-Carlo simulation	11	8%			

Table 1: Distribution of initial search outcome

2.2 Coding scheme for 'research topic'

A major goal of past studies of the IS discipline has been identification of the core of the discipline. Early on, some works of Culnan investigated the core of IS from the reference discipline perspective (Culnan 1986; Culnan and Swanson 1986). Barki et al. (1988) proposed a fundamental but large research classification scheme through a grounded approach. Later coding schemes generally derive from these earlier classification schemes (e.g. Palvia et al. 2007; Vessey and V Ramesh 2002). More recently, adopting a computer-assisted content analysis technique, other coding schemes for IS research topics have been proposed (e.g. Sidorova et al. 2008). The study reported herein employs manual content analysis coding; therefore, prior coding schemes from manual interpretation were considered. Seeking convenience and credibility, this study adopts the coding scheme of research topic from Palvia et al. (2007), a relatively recent and more cited classification scheme.

2.3 Coding scheme for 'level of analysis'

Level of analysis is centrally important in a research. Clarity around level of analysis aides in scoping theory boundaries and identifying research assumptions. Level of analysis can be generally understood as "the entities about which the theory poses concepts and relationships – individuals, groups, organizations, and society" (Markus and Robey 1988, p. 584). By level of analysis, researchers may have different connotations. In this study, we specifically refer to level of analysis as level of theory, which means the combination of levels of all constructs in a theory.

Regarding coding scheme of single level of analysis and multiple level of analysis, this study adopts ideas from mainstream works of level of analysis (Dansereau et al. 1999; Klein et al. 1994; Rousseau 1985; Zhang and Gable 2017). For single level of analysis research we use the codes "individual", "group", "organizational", "industrial", or "societal". For multi-level simulation research, we code both single level of analysis involved and the direction of cross-level effect (i.e. bottom-up or top-down). For example, should a study address group-level IT use, through examining individual-level IT use in the group, it is coded "Multi-level (individual to group)".

Admittedly, it is difficult to distinguish single level of analysis and multiple level of analysis in a simulation study, since most simulation researches involve an implicit multi-level research design in their experimental settings. To address this concern, this research codes level of analysis based on the simulation theory being tested or built and ignores the experimental settings, as variations of variables in experimental settings generally do not influence simulation findings. An outstanding simulation research, Levinthal (1997), finds the structure of an individual affects its competitiveness. All constructs in the simulation theory are in individual level; thus the theory is in individual level. Even if there are some group level constructs (e.g. number of agent in the environment) in the experimental settings, Levinthal (1997) is still considered as a single level of analysis study (individual level) in this research.

2.4 Coding scheme for 'simulation technique'

Simulation technique refers to the specific simulation method adopted. Generally, there are three main kinds of simulation technique: agent-based modelling, system dynamics, and cellular automata (Anderson et al. 1999; Harrison et al. 2007). In addition, Davis et al. (2007) propose other research techniques - NK fitness landscape, genetic algorithm, and stochastic process. For our study purposes, NK fitness landscape is considered as an agent-based modelling technique (Xie and Zhang 2016b), thus coded as agent-based modelling. Davis et al. (2007, p. 489) define stochastic process as "a flexible approach that enables researchers to custom design their simulation". Herein, we consider stochastic process to be a simulation technique that involves random data generation in a simulation process; additionally, the simulation process does not incorporate closed feedback loops and interactions of multiple agents. In other words, we differentiate stochastic process from agent-based modelling and system dynamics. Building on the above literature, this research codes simulation technique as either "agent-based modelling", "system dynamics", "cellular automata", "genetic algorithm", or "stochastic process".

2.5 Coding scheme for 'research approach'

By research approach, we refer to the purpose of the adoption of simulation method. Previous research has emphasized two research approaches in simulation studies: theory building and theory testing (Nan 2011). The distinctive details of these two types are illustrated in the following table. A simulation method may be employed for multiple purposes at the same time. This research codes the main purpose, in terms of data collection and analysis.

Research approach	Purpose of hypothesis	Purpose of simulation	Purpose of simulation finding	Example study
Theory testing	Motivation for model construction and simulation	Computational laboratory for data collection	Empirical evidence for hypothesis testing	Burton and Obel (1980)
Theory building	Uninvolved or as conclusion of simulation	Computational representation of theory	Logical consequence of theory	March (1991), Sastry (1997)

Table 2. Coding scheme of simulation approach (table replicated from table 3 in Nan (2011))

2.6 Coding scheme for 'simulation validation technique'

As laboratory experimentation without much empirical evidence, simulation is often criticized for lacking validity. Therefore, validation process is one critical component of a high quality simulation research. Although methodology of simulation validation is well established in the natural sciences, the social sciences do not prescribe a systematic approach for simulation validation. The existing literature on simulation validation in social science is sparse and is either too general (e.g. Carley 1995; Fraedrich and Goldberg 2000; Law and Kelton 2000) or less related to social science theory (e.g. Kleijnen 1995; Sargent 2005). A single coding scheme from previous literature is less likely to cover all instances in IS simulation research. We are also expecting some adopted simulation validation techniques may not be described by these methodological discussions above. Thereby, having understood the notion of simulation validation, we take an open coding approach to code what validation technique is actually employed in IS simulation research.

3 Coding results

3.1 The quantity history of IS simulation research

Given a sample of journals publish approximately 350 papers per year, and given a maximum of 4 and sometimes zero simulation studies published in any given year since 1988, it is safe to suggest that simulation research is relatively rare in IS. In recent years, the IS research has increased a little bit, but still remains in a limited level. The quantity history of IS simulation publications is presented in figure 1.

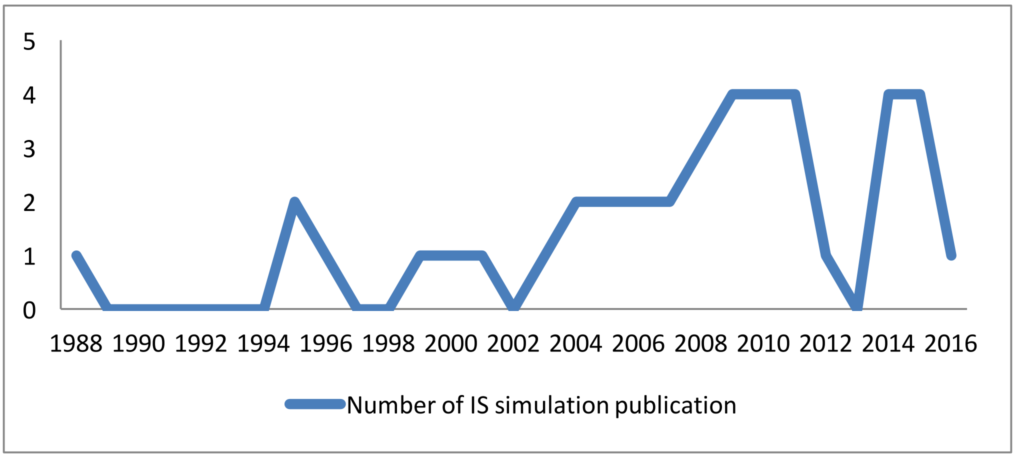

Figure 1: The quantity history of simulation publications in Information Systems discipline

3.2 IS simulation scholars

We found 98 scholars who at least publish one simulation paper. Among them, 14 scholars publish two simulation papers and only 2 scholars publish three. None is found with more publications. The results show that there is no dominant simulation researchers in IS.

Regarding demographic information of the IS simulation scholars, table 3 provides the information of home countries and table 4 presents the information of home institutes. While one might claim that simulation research is more prominent in the U.S. from a national perspective, there are also some institutions from other countries that have relatively notable number of IS simulation scholar. However, given the numbers of simulation scholar in other countries outside U.S. are generally small, the adoption of simulation research is restricted in terms of geographical range.

Home Country	Number of Scholar	Home Country	Number of Scholar
USA	65	France	3
Taiwan	7	Singapore	1
Canada	7	India	1
Australia	5	Chile	1
Hong Kong	3	Germany	1
Korea	3	South Africa	1

Table 3. Home countries of IS simulation scholars

Home Institution	Number of Scholar	Home Institution	Number of Scholar
University of Connecticut	7	Monash University	4
Arizona State University	5	State University of New York at Buffalo	3
University of Minnesota	5	The University of North Carolina at Charlotte	3
McGill University	4	George Mason University	3
National Chin-Yi University of Technology	4	HealthPartners Institute for Education and Research	3

Table 4. Home institutes of IS simulation scholars (threshold = 3)

3.3 Topics in IS simulation research

Table 5 indicates that simulation research has been undertaken in relation to 15 of the 33 categories of IS research in Palvia et al. (2007). Though this is less than half, it nonetheless implies the approach is versatile with regards topic area. Simulation method is more prominent in relation to Electronic Commerce, Management and Network issues, as indicated in the table. During coding (though not separately coded), we sensed that the prominence of studies mainly investigate features of team structure, efficiency, and interaction. Table 5 also lists two topics that do not derive from the Palvia et al. (2007) coding scheme: online community and pricing strategies, which reveals the use of simulation in addressing more contemporary topics.

Category	**Paper amount**	**Category**	**Paper amount**
Electronic commerce/EDI	6	IT value	2
Resource management/IS management issues	5	Organizational design/BPR/workflow systems	2
Artificial intelligence/expert system/neural networks/knowledge management	3	*Pricing strategies*	2
IS usage	3	Group decision support systems	1
Security	3	IS implementation	1
Networks/telecommunications	3	IS planning	1
Online community	3	Outsourcing	1
Decision support systems	2	Software/programming languages	1
Supply chain management (SCM)/ERP	2		

Table 5. Research topics of IS simulation research

3.4 How level of analysis is addressed in IS simulation research

Table 6 illustrates the coding results of level of analysis in IS research. Generally, multilevel research has been scarce in conventional IS studies. However, IS simulation research largely study multilevel phenomena. The multilevel simulation research accounts for 53.4% of our sample, suggesting simulation method has a strong potential to examine multilevel effects.

It is observed that all multilevel studies employ bottom-up perspective. The majority of multilevel simulation researches deal with cross-level effects between individual level and group level (26.8%) as well as individual level and organization level (17%). This is a similar emphasis to the single level simulation research, for which individual level (19.5%) and organizational level (19.5%) comprise 39% in total (which is 44% for multilevel). These outcomes suggest that individual, group, and organizational levels are the main focus of simulation research. It is notable that there is no single level simulation research that addresses the group level of analysis. This may be because the modelling of groups in simulation is readily enhanced by modelling individuals of the group at the same time; therefore, the research becomes multilevel.

(Multi) Level of analysis	**Number**	**%(Approximate)**	**Level of analysis**	**Number**	**%(Approximate)**
Multi-level (Individual to group)	11	26.8%	Individual	8	19.5%
Multi-level (Individual to Organizational)	7	17%	Organizational	8	19.5%
Multi-level (Individual to societal)	2	4.8%	National	1	2.4%
Multi-level (Organization to industry)	1	2.4%	Societal	2	4.8%
Multi-level (Individual/organization /society)	1	2.4%			
Total	22	53.4%	Total	19	46.3%

Table 6. Level of analysis in IS simulation research

3.5 The simulation techniques in IS simulation research

As indicated in table 7, simulation research using agent-based modelling comprises half of IS simulation research (53.7%) in the study sample, well beyond the use of other techniques – stochastic process (24.4%), system dynamics (19.5%), and genetic algorithm (2.4%). This is possibly due to the strong applicability of agent-based modelling technique for most research contexts. In comparison, system dynamics requires precise descriptions of quantitative relationships among various parts of the systems. Thereby, except for supply chain management research, few simulation studies choose to use the system dynamic technique. Similarly, stochastic process requires strong mathematical models and thus simulation research using stochastic process generally comes from the economic background. In this study, no cellular automata research is found. Cellular automata method puts much emphasis on structural position of cells and their network mechanisms. It might be hard to find similar research contexts in Information Systems research.

Simulation technique	Number of paper	%
Agent-based modelling	22	53.7%
System dynamics	8	19.5%
Genetic algorithm	1	2.4%
Stochastic process	10	24.4%

Table 7. Techniques in IS simulation research

3.6 The research approach of simulation research

According to the coding results, only seven IS simulation studies (17%) are primarily doing theory testing; while the rest are mainly doing theory building (83%). Though the theory building approach is more widely used, the theorizing power of simulation method is not appreciated by the main research community (Davis et al. 2007). One possible reason is that the theorizing pattern of simulation research is not typical in social science theorizing. For many, theorizing means arguing causality among constructs. However, simulation research operationalizes in a variable level. Although the relationships among different variables suggest causality among some constructs, the link between variables and these constructs remains unclear. Without shaping simulation theory into typical IS theory, the audience of IS simulation research would be restricted. For instance, Bampo et al. (2008) finds different social structures of digital networks lead to different performances of spreading message in the population. They thus argue the type of network structure plays a critical role in the spread of a viral message. In this case, is the spread of viral message a construct? Does the construct of network act as an antecedent of spread of a viral message; or does it moderate relationships of other constructs in the process of the spread of a viral message?

3.7 Validation techniques of simulation research

18 simulation researches (46%) give no discussions on their employed simulation validation techniques, which is quite concerning. When coding validation techniques in the rest 54% papers, two choices were made explicitly. Firstly, we coded validation techniques from verification techniques as well in literature. Many IS simulation studies use "verify" and "verification" with reference to validation. For example, Wang et al. (2011) refer to the purpose of "verification" as "correction of the conclusion generated by the analysis data" (Wang et al. 2011, p. 318), which in essence means validating the final data. This choice affects coding for 7 simulation researches (17%). Secondly, if some studies mention "calibration", we coded validation technique of calibration process with both labels "Check the structure of simulation model" and "Check parameters in the simulation model". The term "calibration" comes from Carley (1996), covering many processes. Most IS simulation studies mentioned the term of calibration without any detailed descriptions; therefore, we coded their calibration process with the two most important techniques involved in calibration – "Check the structure of simulation model" and "Check parameters in the simulation model".

The final coding results for the existing validation techniques in IS simulation research are illustrated in table 8.

Validation techniques	Descriptions	References[1]
Build on existing models	The simulation model is built by extending or revising existing simulation models.	Park et al. (2015), Choi et al. (2010)
Compare simulation results with results of other model	Results of the simulation model are compared with results of other theoretical models (may or may not be simulation models).	Park et al. (2015), Chang et al. (2010)
Compare simulation	Results of the simulation model are	Abdel-Hamid et al. (1999), Johnson et al.

[1] Due to the page length limit, references in this table are not included in the reference section. The reference list here can be obtained from the author.

results with empirical data	compared with empirical data (often quantitative and in large scale) to check the predictability.	(2014), Sen et al. (2009), Wang et al. (2011), Bapna et al. (2003), Kumar et al. (2008), Bampo et al. (2008), Butler et al. (2014)
Check the structure of simulation model	The structure of the simulation model is tested to ensure that no severe mistakes exist, through structurally a go through, interviewing experts' opinions, and so on.	Li and Madnick (2015), Choi et al. (2010), Chiang and Mookerjee (2004), Kwon et al. (2007), Nazareth and Choi (2015), Butler et al. (2014)
Compare key behavior outcomes of simulation model with real world phenomenon	Typical outcomes of the simulation model are compared with real-world data, which is often not quantitative, for example, behavioral patterns.	Li and Madnick (2015), Park et al. (2015), Bapna et al. (2003), Nan and Johnston (2009), Nan (2011), Choi et al. (2010), Meyer et al. (2014), Nazareth and Choi (2015), Dutta and Roy (2005)
Sensitive analysis	This technique systematically varies parameter inputs and then determines their effects on the model outputs.	Li and Madnick (2015), Park et al. (2015), Bapna et al. (2003), Nan and Johnston (2009), Nan (2011), Choi et al. (2010), Meyer et al. (2014), Nazareth and Choi (2015), Dutta and Roy (2005)
Replicate experiment	The simulation experiment is repeated several times to make sure that same outcomes can be obtained in every separate experiment.	Abdel-Hamid et al. (1999), Sen et al. (2009)
Extreme condition test	The parameter inputs of simulation model are set in extreme conditions, and then examining whether model outputs are plausible.	Abdel-Hamid et al. (1999), Nazareth and Choi (2015), Port and Bui (2009)
Check face validity	Ask knowledgeable individuals whether there are apparent mistakes in different sections, for example, operationalization, initial parameter settings, and model outcomes of simulation research.	Guo et al. (2012), Li and Madnick (2015), Abdel-Hamid et al. (1999)
Check measurement validity	The operationalization of constructs is tested by empirical data.	Chen and Fong (2015)
Check parameters in the simulation model	Use empirical data to test whether the parameter values in the simulation model represent the real world phenomena.	Li and Madnick (2015), Johnson et al. (2014), Bapna et al. (2003), Kumar et al. (2008), Dawande et al. (2008), Choi et al. (2010), Butler et al. (2014)

Table 8. Summary of simulation validation approaches in IS simulation research

As illustrated in the table 8, various simulation validation techniques have already been adopted in IS simulation research. However, these validation techniques can only test one or two kinds of validity. For instance, the mostly adopted four kinds of validation techniques (the 3rd to 6th techniques in table 8) generally serve for external validation purposes. In other words, these validation techniques can generally ensure the simulation results are applicable in the real world. However, they cannot check whether the simulation model is correct (internal validity), whether the operationalization measurement is appropriate (construct validity), and so on. Most simulation researches would only employ one or two kinds of validation technique, so the overall validity of simulation theory has not been examined. Admittedly, simulation research is different from conventional IS research; hence, the validity concerns may be different. Even though, the coding result suggests current validation process of IS simulation research is still less systematic.

3.8 Highly cited IS simulation literature

We tried to identify patterns of highly cited IS simulation literature based on citations. However, the results do not reveal any obvious patterns in terms of research topic, level of analysis, simulation technique, and research approach, mainly because of small number of IS simulation publications. Most simulation studies (78%) in the sample have less than 20 citations in *WebofScience* database; the mostly cited IS simulation research is Bampo et al. (2008), with only 78 citations.

4 Discussions

Currently, the definition of simulation research is understood in various styles, as demonstrated in the initial literature search outcome (table 1). We contend the term of simulation research should be specifically referred to computational modelling. Some scholars may hold the view that human experimentation is one kind of simulation method (e.g. Spagnoletti et al. 2013). Though computational modelling of simulation and human experimentation are both simulating real world phenomena, the two methods are under different research paradigms. Their research designs, research processes, and validity concerns are largely different. If the two different research methods are discussed together, general methodological prescriptions are hard to produce. Therefore, in order to increase the identity and clarity of simulation method, future research should consistently refer to simulation research only as computational modelling.

The coding results demonstrate several patterns of simulation research, which implies opportunities of future simulation research. In terms of research topics, simulation method is largely used in electronic commerce, management, and some other topics. Researchers can consider simulation method when investigating related areas, for instance, the recent burgeoning sharing economy. Two simulation techniques, system dynamics and stochastic process, are found to be employed specifically in supply chain management and economic areas, suggesting these simulation techniques has some advantages in these fields. In addition, simulation research is largely used for multilevel theorizing. When needing to examine cross-level effect, researches could consider the possibilities of simulation method. Yet, taking advantage of the existing usage does not mean forsaking unexplored areas. Actually, we believe many research opportunities lie in these unfarmed grounds. Half of research topics in Palvia et al. (2007) classification system are not addressed in current simulation research. We consider the reason as the lack of clarity and appreciation of simulation method instead of its defects, given the number of simulation publication is quite small. We see many possibilities in some less addressed or unaddressed areas in the classification scheme of Palvia et al. (2007), for example, IT value (e.g. Xie and Zhang 2016a).

Apart from opportunities of empirical simulation research, research findings also suggest two directions for future methodological discussions of simulation – the multilevel theorising and validation process in simulation research.

Level of analysis issues have always been the central concerns in research. Multiple level of analysis issues are rather important. They better represent the real world phenomena; however, studying multilevel theory is also complicated. Currently, our understanding of multilevel theorizing process is limited (Zhang and Gable 2017). According to the research findings, main simulation researches adopt multilevel theorising approach, suggesting that this is a typical feature of simulation method. A promising direction is to discuss how simulation method theorise multilevel theory. Such research would greatly contribute to both multilevel theorizing and simulation methodology areas.

Although it is argued validation is a critical step for simulation research (Davis et al. 2007), the simulation validation in IS is less well addressed. Nearly half IS simulation researches do not report their validation processes. The rest only employ few validation techniques separately. These findings reflect the fact that the IS community lacks a systematic prescription of simulation validation process. Though some may argue systematization is not always necessary, we contend that systematization can facilitate integration and transparency, thus increasing clarity and promoting appreciation. Regarding the roadmap of discussing simulation validation process, we further provide some thoughts herein. For validation of conventional research methods, many strong works have been published. For example, Cook et al. (1979) propose validity in quantitative methods can be covered by "statistical conclusion validity", "internal validity", "construct validity", and "external validity". Venkatesh et al. (2013) propose three categories of validity in quantitative research: "design validity", "measurement validity", and "inferential validity"; while similarly for qualitative methods, the categories are "design validity", "analytical validity", and "inferential validity". Future research can map the existing knowledge of simulation validation techniques into previous validity frameworks of conventional methods, thus proposing guidelines of simulation validation process.

5 Limitations and future works

The results reported herein are based on the author's own coding and interpretation and thus they might be biased. The research questions are quite general; the literature is restricted to IS discipline; the journals are not overwhelmingly inclusive; some coding logics may be arguable (e.g. level of analysis); the research outcomes are quite preliminary; the findings are largely descriptive. The authors admit these defects and call for further considerations on these issues. Future works should address the following issues. Coding logics should be further elaborated. A second coder needs to be involved to increase the inter-coder reliability. Some highly cited simulation literature at other IS journals can be incorporated; simulation literature from IS-related disciplines can be involved as well, such as management, business, and economics, for comparing IS simulation research with simulation research in other disciplines. Further, the conduct of coding and data analysis could seek assistance from some theoretical lens. For example, how do different simulation researches address "value construction" based on the framework of Zhang and Gable (2014)?

6 Conclusions

The objective of this research is to understand how simulation research method has been employed in Information Systems Discipline, thus facilitating future empirical simulation research and methodological discussions in IS discipline. Content analysis is employed to discover author information, research topic, level of analysis, research techniques, research approach, validation approaches, and other information in IS simulation research. Coding results reveal several findings. Simulation research has not received much attention is IS discipline. The utilisation of simulation method is limited. However, the coding results also suggest that simulation has power in addressing certain research topics and multilevel theorizing.

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