

Discrete Event Simulation in Business Processes Management Projects – a Preliminary Literature Review

Vesna Bosilj Vukšić, Mirjana Pejić Bach

University of Zagreb, Faculty of Economics and Business

Department of Informatics

Trg J.F.Kennedya 6, Zagreb, Croatia

vbosilj@efzg.hr, mpejic@efzg.hr

Katarina Tomičić-Pupek

University of Zagreb, Faculty of Organization and Informatics

Department of Information Systems Development, Pavlinska 2, Varaždin, Croatia

ktomicic@foi.hr

Abstract. Nowadays business process management projects are very strongly focused on methods and software tools for process modelling, change and automatization. On the other hand, the efforts to gain the benefits that can be assessed by using discrete event simulation modeling in business process management projects are still rarely reported. The purpose of this paper is to provide a systematic analysis of research paper in order to shed some light in this area. This literature overview could help academics and business practitioners for the further development of this field.

Keywords. Discrete event simulation, business process management, project, literature review

1 Introduction

Business process management (BPM) represents a holistic approach to managing processes, from design and analysis through implementation, to monitoring and ongoing optimization (Rosemann and vom Brocke, 2015). Commonly, the technologies that are used for this are called business process management system (BPMS). The majority of BPMSs available on the market today include discrete event simulation (DES) facilities that empower business users to model current or proposed processes, and use simulation for the analyses, testing and optimizing those processes.

The purpose of this paper is to provide an overview of articles focusing on DES implementation in BPM projects and to investigate the role of DES in BPM projects' outcomes. A systematic literature review was performed in order to achieve the research goals. This work has been fully supported by Croatian Science Foundation under the project PROSPER - Process and Business Intelligence for Business Performance (IP-2014-09-3729). The PROSPER

project aims to explore the adoption of process and business intelligence in organizations and their impact on the organizational performance with the special focus on using modern technologies in their implementation.

Goals of our analysis are: (RQ1) to analyze the longitudinal trend of the DES reporting in BPM projects, (RQ2) to analyze the research areas of the papers that report usage of DES in BPM projects, and (RQ3) to analyze the industries with case studies that report usage of DES in BPM projects. Fourth goal (RQ4) of the project was to analyze the impact of DES implementation on the success of BPM projects, which is also one of the objectives of the PROSPER project.

The paper has been organized as follows. After the introduction, the next section of the paper provides a theoretical background concerning DES, particularly its applications in BPM. Section 3 describes the research methodology. The analysis and discussion of the research results is presented in the Section 4. Finally, a short conclusion with the limitations and plans for future research is given.

2 Theoretical background

According to Banks (2000) simulation is used to describe and analyze the behavior of a system, ask "what if" questions about the real system and aid in the design of real systems while. It refers to a range of model types, such as spreadsheet models, system dynamic simulations and DES modelling. DES is used to analyze systems in which the state variables change only at those discrete points in time at which events occur. Since it is suitable to be used in the context of business-process reengineering (BPR) and of other process-based change methods, the technique

is also referred to as business process simulation (Aguilar et al., 1999).

BPMS are software applications that enable the modelling, execution, monitoring and user representation of business processes and rules (Ravesteyn and Versendaal, 2007). The authors mostly refer to a variety of terms, such as BPM tool, suite and platform. According to Margherita (2014) a BPMS consists of four subsystems: (1) process strategy; (2) process model; (3) process execution; and (4) process performance. The process model subsystem is addressed to design business process repository of the company. This subsystem includes value chain model; process models and simulation; stakeholders and process roles; and business rules and governance. So, DES is considered a constituted part of modelling and analysis which are the first phase of the BPM lifecycle by the Service Oriented Architecture (Juric and Pant, 2008). Process simulation supports process analysis in the sense that business users can construct "what if" scenarios to see how AS-IS processes perform, to compare the outcomes of potential alternative process designs and to propose modifications of the original model (van der Aalst, 2013, Bosilj Vuksic et al., 2002).

Many researchers advocate the use of DES for the modeling of process dynamics and for analyzing their operational performance (Bisogno et al., 2016). According to Bolsinger et al. (2015) there is a high demand for practical approaches to business process performance analysis, and DES is considered a good method to achieve this goal. It is highly suggested to use in BPM projects as it allows business users to get the knowledge about the essence of business system, to propose the changes and to understand the impact of proposed changes on process performance. The research results showed that the application of DES helps to avoid failure of BPM projects (Peček et al., 2011; Bertolini et al., 2011; Bosilj Vuksic et al., 2002). Besides, only an integrated simulation approach that includes both the business processes and organizational structure can significantly affect business process performance (Lee et al., 2015). Many BPMS vendors provide simulation functionality as an added component to their platforms. According to Dumas et al. (2013) it is convenient to use business process simulation for fine-gained analysis since it allows deriving process performance measures and data about the resources involved in the processes. Still, BPMS are offering limited simulation functionality compared to the features that have specialized simulation software (Mahal, 2010).

Despite the numerous advantages of simulation, Bisogno et al. (2016) emphasize that researchers in organizational and management studies did not regularly use simulation and tended to overlook its potential contribution to their work. Most BPM projects teams turn to specialists to undertake simulation studies, and those specialist often prefer to use especially designed and the more sophisticated

simulation tools (Mahal, 2010). However, during the last two decades the simulation approaches began to be more frequently published in the major management, information systems, computer science and operations research management journals. Through the years DES is being widely used in manufacturing but also in areas such as health care, military, traffic modeling and service industry (Bosilj Vuksic et al., 2002).

3 Research Approach

According to the authors a literature review is a mean to summarize past findings in a research field and to find out areas where further research is needed (Cooper, 2010; Webster and Watson, 2002). Tables 1 and 2 present our search strategies in WoS and Scopus, with the time span (1995-2015).

Table 1. WoS search strategy (1995-2015)

Search strategy	Hits	Time span	Indexes
((business process) AND (discrete AND simulation))	89	All years	SCI-EXPAN D., SSCI, A&HCI, ESCI
Refined by: WoS CATEGORIES: (OPERATIONS RESEARCH MANAGEMENT SCIENCE OR COMPUTER SCIENCE INTERDISCIPLINARY APPLICATIONS OR MANAGEMENT OR COMPUTER SCIENCE INFORMATION SYSTEMS OR ECONOMICS)	60	All years	SCI-EXPAN D., SSCI, A&HCI, ESCI

Table 2. Scopus search strategy (1995-2015)

Search strategy	Hits	Time span	Indexes
TITLE-ABS-KEY (((business process) AND (discrete AND simulation)))	331	All years	Scopus
SUBJAREA (mult OR arts OR busi OR deci OR econ OR psyc OR soci) AND LIMIT-TO (SUBJAREA,"DECI")	74	All years	Scopus

OR LIMIT TO (SUBJAREA , "BUSI") OR LIMIT TO (SUBJAREA , "COMP") OR LIMIT TO (SUBJAREA , "ECON")) AND (LIMIT TO (DOCTYPE, "ar"))			
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We conducted a search using the scientific databases Web of Science (WoS) and Scopus in February 2016. Through the first part of the search we checked WoS and Scopus using keywords: “business process” AND “discrete” AND “simulation”. The search was focused on peer-reviewed articles in journals. In the next step, the search strategy was refined. Since DES is applied in different avenues of scientific research we decided to limit our research to specific fields in social sciences and computer science. This criterion was related to Scopus subject areas and WoS categories (Table I and II). The second search resulted with 134 hits (74 hits in Scopus and 60 hits in WoS).

In our analysis we have included 134 articles (60 from WOS and 74 from Scopus). However, 26 articles were in both databases. Therefore, 108 articles remained for the analysis. After reviewing the abstracts and keywords of all 108 articles, we eliminated articles which did not report the description of the DES in the BPM project. We used the following criterion. Article was considered relevant, if it specifically covers the case study of discrete event simulation in BPM project. Finally, after applying this exclusion criterion 54 publications remained, and they represent the basis for our further analysis. Next, we extracted and coded relevant data of surveys (e.g. authors, title, and journal, year of publication, sample industry, covered BPM and DES factors) for our analysis.

4 Analysis of papers with described DES in BPM projects

Figure 1 depicts the annual number of publications from 1994 to 2015. A growing trend of published papers is revealed. Most of the papers (39) were published from 2005 to 2015. This result is aligned with the results of the studies conducted by Shaver and Smunt (2004) and Harrison et al. (2007) who showed that it was at the beginning of the 1990s that DES began to appear more frequently in the scientific journals.

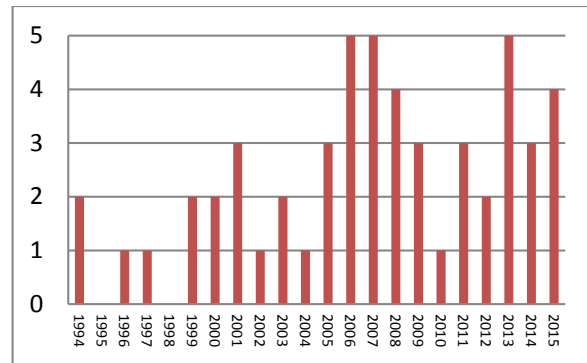


Figure 1. Number of published papers per year with described DES in BPM projects

Further, the published papers were grouped in 5 categories in relation to the discipline or field they belong to. An analysis of the papers indicates that the biggest number of papers (25) comes from the field of “Operational research (including decision support, expert systems and simulation)”, but the second ranked category was “Management, business, economics and information systems” with 12 articles. This result is well matched with the findings presented by Bisogno et al. (2016).

Table 3. Research areas of the papers with described DES in BPM projects

No.	Research area of the paper (discipline)	Paper ID	# of papers
1	Operational research (including decision support, expert systems and simulation)	1, 3, 5, 8,10, 11, 13, 14, 15, 16, 21, 23, 24, 25, 27, 28, 31, 33, 38, 39, 44, 47, 48, 49, 54	25
2	Management science, Information systems and Economics	6, 20, 22, 30, 32, 36, 41, 43, 45, 46, 51, 52	12
3	Computer science and Computer engineering	2, 4, 7, 17, 42	5
4	Interdisciplinary	12, 34, 35, 37, 53	5
5	Specific industries	9, 18, 19, 26, 29, 40, 50	7
Total			54

By summarizing articles according to the industry-type of companies that conducted BPM projects, we derived 12 categories depicted in Figure 2, which are in line with the NACE industry classification. Detailed referenced results are listed in Table 4.

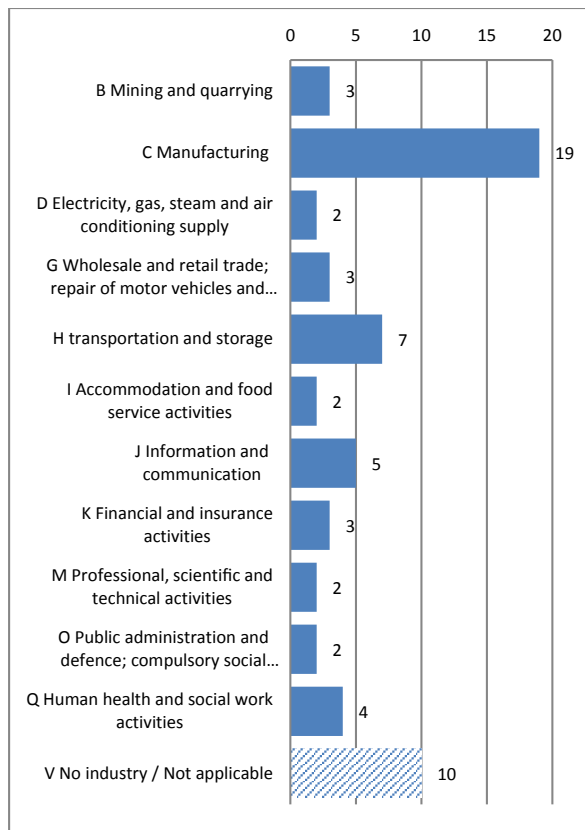


Figure 2. Number of case studies per industry-type

Table 4 portrays the detailed results of the industry-type per case study. First, it has to be noted that one of the papers present more than one case study, with different industries (e.g. ID 31 presents 6 case studies, from following industries: 3 case studies from the Industry C, 1 from Industry G, 1 from Industry H, and 1 from Industry I). Therefore, number of case studies presented in the Table 4 (62) is larger than the number of the papers (54).

The largest number of the case studies (19) is reported in Industry C-Manufacturing, which is followed by the Industry H-Transportation and storage with 7 case studies. Industries related to services, e.g. Industry K Financial and insurance activities reports only 3 case studies, which is substantially lower in comparison with Industries C and H.

Table 4. Industry-type presented in the case study

Industry-type	Case studies per industry-type	Paper ID
B Mining and quarrying	3	1, 46, 51
C Manufacturing	19	4, 8, 9, 11, 15, 16, 17, 18, 21, 23, 25, 26, 28, 31 (3 case studies), 33, 35,

		49
D Electricity, gas, steam and air conditioning supply	2	37,52
G Wholesale and retail trade; repair of motor vehicles and motorcycles	3	22, 28, 31
H Transportation and storage	7	12, 19, 20, 28, 31, 39, 54
I Accommodation and food service activities	2	13, 31
J Information and communication	5	3, 5, 7, 41, 48
K Financial and insurance activities	3	6, 15, 30
M Professional, scientific and technical activities	2	38, 43
O Public administration and defence; compulsory social security	2	24, 32
Q Human health and social work activities	4	27, 29, 45, 50
V No industry / Not applicable	10	2, 10, 14, 34, 36, 40, 42, 44, 47, 53
Total	62	54

Table 5 presents the success of the BPM project in the paper. Our goal was to evaluate the positive and negative effects of implementations of simulation as a predictive method in simulation in business processes reengineering projects. However, since none of the papers reported that the BPM project was not successful, it was not applicable to evaluate the impact of DES to success of the BPM project. The results of this analysis revealed that 54 reviewed articles can be categorized into two groups: (1) successful BPM project and (2) projects where clear description of the success was not presented. Most of the papers reported that BPM project was successful. However, the papers did not implicitly report that the success was the result of the DES usage.

Table 5. BPM Project's success in published papers

NO.	Project's success	Paper ID	# of papers
1	Reported	1, 3, 4, 5, 6, 7, 9, 11, 12, 13, 15, 18, 19, 20, 22, 23, 24, 25, 27, 28, 29, 30, 31, 32, 33, 35, 37, 38, 39, 41, 43, 45, 49, 50, 51, 52, 54	34
2	Not applicable	2, 8, 10, 14, 16, 17, 21, 26, 34, 36, 40, 42, 44, 46, 47, 48, 53	17

5 Conclusion

The purpose of the paper was to provide the results of the systematic analysis of research paper in order to reveal trends in usage of DES in BPM projects. In order to attain this goal, we have conducted the search of the scientific databases WoS and Scopus with the time span from 1995 to 2000, using key words (business process) AND (discrete AND simulation). Our search revealed 54 papers that describe the case studies of the DES usage in BPM projects.

We have revealed the following results in relation to the research goals. First, we have conducted the longitudinal trend analysis of the DES reporting in BPM projects (RQ1) that revealed that most of the papers were published from 2005 to 2015, which is in line with the research of other authors (Shaver and Smunt, 2004; Harrison et al., 2007). Second, we have conducted the analysis of the research areas of the papers that report usage of DES in BPM projects (RQ2) that revealed that most of the papers were published in these two areas "Operational research (including decision support, expert systems and simulation)", and "Management, business, economics and information systems". Third, we have analyzed the industries with case studies that report usage of DES in BPM projects (RQ3), which revealed that most of the case studies were applied in industries C-Manufacturing and H-Transportation and storage. Several case studies reported the applications in service industries, like K Financial and insurance activities. Finally, we tried to analyze the impact of DES implementation on the success of BPM projects, but we were not able to clearly attain this goal, since most of the projects do not implicitly describe this impact.

The presented results are part of the larger research that investigates the usage of DES in BPM projects, and in this paper we present preliminary results, that reveal important longitudinal trends related to the research areas and industry applications.

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APPENDIX 1: List of selected articles

No	Article reference
1	Potter, A., Yang, B., Lalwani, C.: A simulation study of despatch bay performance in the steel processing industry. <i>EUROPEAN JOURNAL OF OPERATIONAL RESEARCH</i> Volume: 179 Issue: 2 Pages: 567-578, 2007
2	Gutjahr, WJ., Strauss, C., Wagner, E.: A stochastic branch-and-bound approach to activity crashing in project management. <i>INFORMS JOURNAL ON COMPUTING</i> Volume: 12 Issue: 2 Pages: 125-135, 2000
3	Janssen, M., Verbraeck, A.: An agent-based simulation testbed for evaluating internet-based matching mechanisms. <i>SIMULATION MODELLING PRACTICE AND THEORY</i> Volume: 13 Issue: 5 Pages: 371-388, 2005
4	Chan, KK., Spedding, TA.: An integrated multidimensional process improvement methodology for manufacturing systems. <i>COMPUTERS & INDUSTRIAL ENGINEERING</i> Volume: 44 Issue: 4 Pages: 673-693, 2003
5	Dorsch, C., Hackel, B.: Combining models of capacity supply to handle volatile demand: The economic impact of surplus

	capacity in cloud service environments. <i>DECISION SUPPORT SYSTEMS</i> Volume: 58 Special Issue: SI Pages: 3-14, 2014
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8	Doerner, K., Gutjahr, WJ., Kotsis, G., Polaschek, M., Strauss, C.: Enriched workflow modelling and Stochastic Branch-and-Bound. <i>EUROPEAN JOURNAL OF OPERATIONAL RESEARCH</i> , Volume: 175 Issue: 3 Pages: 1798-1817, 2006
9	Kumar, S., Nottestad, D.: A Flexible capacity design for the Focus Factory - a case study. <i>INTERNATIONAL JOURNAL OF PRODUCTION RESEARCH</i> Volume: 47 Issue: 5 Pages: 1269-1286 Article Number: PII 783361911, 2009
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12	Andriulo, S., Elia, V. Gnoni, MG.: Mobile self-checkout systems in the FMCG retail sector: A comparison analysis. <i>INTERNATIONAL JOURNAL OF RF TECHNOLOGIES-RESEARCH</i> , Pages: 207-224, 2015
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15	Mulekar, MS., Matejckik, FJ.: On selecting

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16	Kleijnen, JPC., Smits, MT.: Performance metrics in supply chain management. JOURNAL OF THE OPERATIONAL RESEARCH SOCIETY Volume: 54 Issue: 5 Pages: 507-514, 2003	26	Vernadat, F., Shah, L., Etienne, A., Siadat, A.: VR-PMS: a new approach for performance measurement and management of industrial systems. INTERNATIONAL JOURNAL OF PRODUCTION RESEARCH Volume: 51 Issue: 23-24 Pages: 7420-7438, 2013
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