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Survey Paper

Utilization of Discrete Event Simulation in Business Processes Management Projects: a Literature Review

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Abstract

Discrete event simulation (DES) software is often used in business process management (BPM) projects, in order to support modeling, change and automatization of process modeling. However, the current research lacks systematic overview of the benefits and pitfalls of using DES software for BPM. The goal of this paper is to provide a systematic analysis of research paper related to the operations research, computer science, business and management that report the usage of DES in BPM projects, in order to shed some light in this area. Results of this analysis could be useful to academics and business practitioners in their projects.
Keywords: Discrete event simulation, business process management, project, literature review

1. Introduction

Business process management (BPM) is widely used for managing processes, from design and analysis through implementation, to monitoring and ongoing optimization [1]. Software solutions that are widely used in order to support BPM, are often called business process management system (BPMS).

Discrete event simulation (DES) is developed for the purpose of analyzing behavior of the systems and conducting experiments with the changes in system structure, using discrete variables for the description of the systems. DES is often used as a method and tool for the support of BPM, and is then referred to as business process simulation. In most of the BPMSs, the DES facilities are included in order to support business users in modeling current and proposed processes, and utilize simulation for conducting experiments that are basis for the process optimization.

The goal of the paper is to present a systematic review of papers that present implementation of BMP projects with the application of DES, with the specific focus to the role of DES in BPM projects' outcomes. In our research we focus to the papers in the fields of operational research, computer science, business and management.

In order to attain this goal, we have conducted a systematic literature review. 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.

Research goals of the project are: (RQ1) to analyze the longitudinal trend of the DES reporting in BPM projects, (RQ2) to analyze the industries with case studies that report usage of DES in BPM projects. Third goal (RQ3) of the project is 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. The research methodology description is followed by the analysis and discussion of the research results. Finally, a short conclusion with the limitations and plans for future research is given.

2. Theoretical background

According to Banks [2], "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". It refers to a variety of model types, from models developed as spreadsheets, over models based on system dynamic simulations to complex DES models. DES is used to analyze systems whose behavior can be analyzed through tracking change of state variables while they are describing discrete sequences of events that occur in time. Since it is suitable to be used for evaluating various process scenarios within business process improvement, business process reengineering and other process related endeavors, the implementation of simulation for this purpose is also referred to as business process simulation [3].

BPMS are software applications "that enable the modelling, execution, monitoring and user representation of business processes and rules" [4]. The authors mostly refer to a variety of terms, such as BPM tool, suite and platform. According to Margherita [5] "a BPMS consists of four subsystems: (1) process strategy; (2) process model; (3) process execution; and (4) process performance". The process model subsystem is dealing with the overall structure of company's processes and "includes value chain and system model; process models and simulation; stakeholders and process roles; and business rules and governance" [6]. 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 [7]. 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 [8], [9].

Many researchers advocate the use of DES for the modeling of process dynamics and for analyzing their operational performance [10]. According to Bolsinger et al. [11] 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 [12], [13], [9]. Besides, “only an integrated simulation approach that includes both the business processes and organizational structure” [14] can significantly affect business process performance. Many BPMS vendors provide simulation functionality as an added component to their platforms. According to Dumas et al. [15] 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 [16].

Despite the numerous advantages of simulation, Bisogno et al. [10] 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 [16]. 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 [9].

3. Research Approach

In our research we have used the literature review, as a mean to summarize past findings in a research field, in our case usage of DES in BPM projects [17], [18]. Our selection process of the papers for the literature review is presented in figure 1.

First, we identified relevant databases for our research, and we have decided to focus to the peer-review journals that are cited in Scopus and WoS (SSCI and SCI papers). Tables 1 and 2 present our search strategies in WoS (SSCI and SCI) and Scopus, with the time span (1994-2015).

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 papers in journals. This approach resulted with 420 hits (89 hits in Scopus and 331 hits in WoS).

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 the papers in the fields of operational research, computer science, business and management. This criterion was related to Scopus subject areas and WoS categories (Table 1 and 2). The following WoS categories are used: Operations research management science, Computer science, Interdisciplinary applications, management, Computer science information systems, Economics. The following Scopus categories are used: Operational Research, Decision making, Business, Computer science and Economics. This approach resulted with 134 hits (74 hits in Scopus and 60 hits in WoS).

Search strategy	Hits	Time span	Indexes
((business process) AND (discrete AND simulation))	89	All years	SCI-EXPAND., 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-EXPAND., SSCI, A&HCI, ESCI

Table 1. WoS (SSCI, SCI) search strategy (1994-2015)

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") OR LIMIT TO (SUBJAREA , "BUSI") OR LIMIT TO (SUBJAREA , "COMP") OR LIMIT TO (SUBJAREA , "ECON")) AND (LIMIT TO (DOCTYPE, "ar"))	74	All years	Scopus

Table 2. Scopus search strategy (1994-2015)

In our analysis we have included 134 papers (60 from WOS and 74 from Scopus). However, after merging all papers, we excluded 26 papers which were found in both databases. Therefore, 108 papers remained for the analysis. After reviewing the abstracts and keywords of all 108 papers, we eliminated papers which did not report the description of the DES appliance in the BPM project. We used the following criterion. Paper was considered relevant, if it specifically covers the case study of discrete event simulation in BPM project.

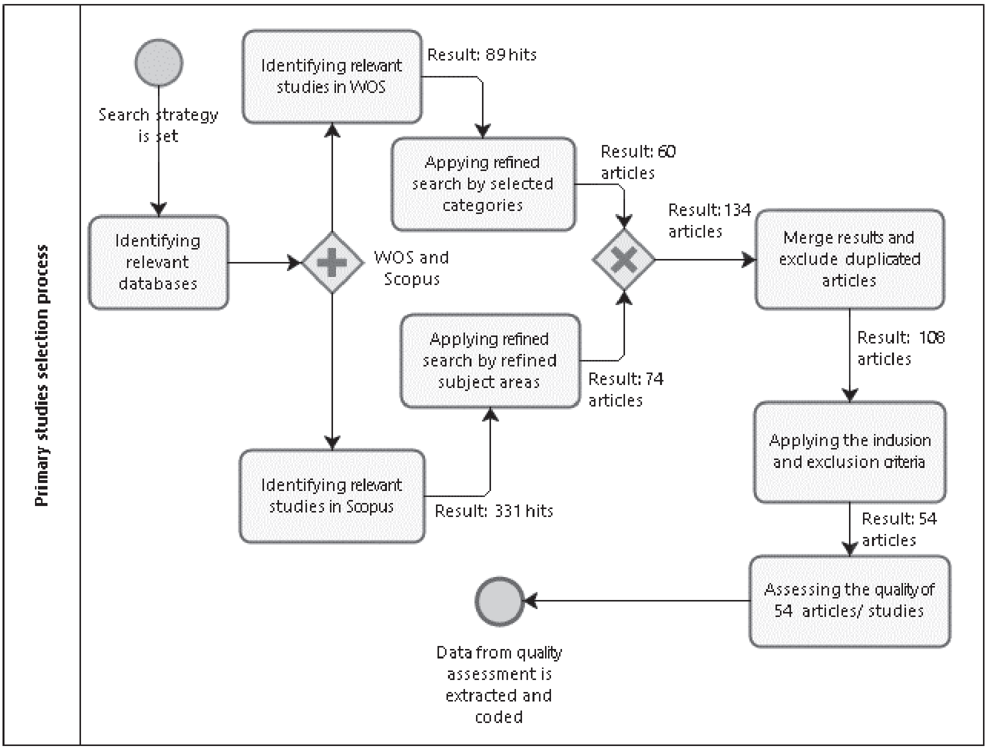

Figure 1. Selection process of the papers for the literature review

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, BPM and DES success factors) for our analysis.

4. Analysis of papers with described DES in BPM projects

Figure 2 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 Shafer and Smunt [19] and Harrison et al. [20] who showed that it was at the beginning of the 1990s that DES began to appear more frequently in the scientific journals.

By summarizing papers according to the industry-type of companies that conducted BPM projects, we derived 12 categories depicted in Table 3, which are in line with the NACE industry classification. Detailed referenced results are listed in Table 3.

Table 3 portrays the detailed results of the industry-type per case study. First, it has to be noted that some 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 manufacturing industries, 1 from Wholesale and retail trade, 1 from Transport and storage, and 1 from Information and communication). Therefore, number of case studies presented in the Table 4 (62) is larger than the number of the papers (54).

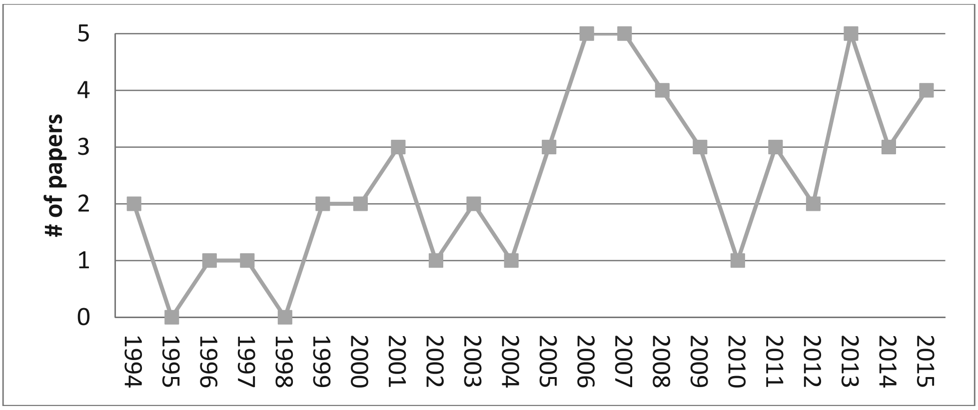

Figure 2. Number of papers published per year with described DES in BPM projects

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

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 defense; 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 3. Industry-type presented in the case study

5. DES critical success factors in BPM projects

Though many researchers tried to identify a positive correlation between BPM project and organizational success, the findings showed that BPM project success did not always result in increased organizational performance [21]. According to Thompson, Seymour and O'Donovan [22] BPM project success is achieved "only when BPM initiative leads to measurable degrees of business success". Some authors argue that BPM success influence organizational performance indirectly, through process performance improvement [22]. Besides, the researchers very often define a theoretical BPM success model as a set of CSFs of BPM project [23], [24], [21]. The same approach is applied in this research in order to investigate the link between the introduction of DES in BPM projects and projects' success.

No.	Project's success	Paper ID	# of papers
1	Reported explicitly	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	37
2	Reported implicitly	2, 8, 10, 14, 16, 17, 21, 26, 36, 40, 42, 44, 46, 47, 48, 53	16
3	Not applicable	34	1

Table 4. BPM Project's success in published papers

The implementation of DES is a time-demanding and complex endeavor and its outputs depend on various factors. Evaluating and selecting simulation software is a difficult process. This has led researchers to investigate methodologies for selecting software evaluation criteria and evaluation techniques [25]. However, simulation software selection is only one of many factors that may affect the success of DES implementation in business process simulation projects [26], [27], [28]. Consequently, many research studies aim to find and explain the critical success factors (CSFs) of simulation projects [29], [30], [31]. Similarly, academics and business practitioners are very often focused on identifying and explaining the CSFs of BPM projects [32]. Although general CSFs are well understood, we argue that specific CSFs must be taken into account in a case of DES implementation in BPM projects. Therefore our literature review aims to provide brief insights into the most frequently identified DES CSFs in BPM projects.

First, 54 papers are analyzed and distributed into two groups based on the report on DES CSFs role in BPM project success. The results of this analysis reveal that in 37 papers DES CSFs and its' significance for BPM success are explicitly described while in the case of 16 papers these are described implicitly, but detailed enough to be analyzed (Table 4). This classification criterion was not applicable for one paper that was not available in English.

Next, the BPM success factors identified by Bai and Sarkis [33], Van Looy et al. [34] and Buh et al. [32] are gathered and analyzed. Bai and Sarkis [33] identified 8 main CSFs in their study. Van Looy et al. [34] systemized 6 main capability areas (modeling, deployment, optimization, management, culture and structure) and 17 subareas while Buh et al. [32] presented a comprehensive list of 13 factors (Appendix 2). Each of these factors describes a unique strategy that would positively influence the success of BPM implementation. Based on the results of the analysis its' elements are mapped to 7 categories that seemed likely to explain most of the factors (Table 5). Table 5 does not include CSFs related to performance measurement, optimization and improvement (e.g. Bai and Sarkis [33]: 4; Van Looy et al. [34]: 4, 5, 6; Buh et al. [32]: 9, 12). These factors are implied if simulation project is conducted and therefore are not further explored.

CSFs Categories of BPM projects	Sources
PROVIDER	Bai and Sarkis [33]: 3, 5
SOFTWARE	Bai and Sarkis [33]: 6 Van Looy et al. [34]: 3 Buh et al. [32]: 6
METHODS, MODEL DEVELOPMENT AND DATA INPUT/OUTPUT	Van Looy et al. [34]: 1, 2 Buh et al. [32]: 4
ORGANIZATIONAL CULTURE AND PEOPLE	Bai and Sarkis [33]: 7 Van Looy et al. [34]: 10, 12, 13, 14 Buh et al. [32]: 3, 7, 11
COMMUNICATION	Bai and Sarkis [33]: 8 Buh et al. [32]: 5
TOP MANAGEMENT SUPPORT AND STRATEGIC ALIGNMENT	Van Looy et al. [34]: 7, 8, 9, 11, 15 Buh et al. [32]: 1, 2, 13
GOVERNANCE	Van Looy et al. [34]: 16, 17 Buh et al. [32]: 8, 10

Table 5. Categories of CSFs in BPM projects

Finally, the simulation success factors defined by Robinson [35], Robinson and Pidd [36] are used to develop CSFs framework for DES implementation in BPM projects. The study conducted by Robinson and Pidd [36] examines and analyzes gap in expectations between simulation provider and customer in simulation projects. A set of 19 dimensions in the delivery of a simulation project was developed (the 'Other' category included a small number of factors that did not fit the other 18 groups, according to Pidd [37]). The results of this study have also been adopted by some very prominent researchers (e.g. Altsitsiadis [38], Jahangirian et al. [29]). For the purpose of this research 19 dimensions of DES CSFs were mapped into previously defined 7 categories of CSFs for BPM (Table 5). The term "*Provider*" in Table 6 is used for simulation project team, top-management, consultants and software providers. "*The Customer*" is term used for internal customer (e.g. user) or enterprise that introduces DES in BPMS project.

CSFs Categories of BPM projects	Simulation success factors (dimensions) according to Robinson and Pidd [36]
PROVIDER (Bai and Sarkis [33])	1.1. Credibility of the Provider: trustworthiness, believability and honesty of the provider and his/her organization 1.2. Competence of the Provider: possession of the necessary skills and knowledge by the provider and his/her organization to perform the simulation project 1.3. Professionalism: the provider's commitment (to the project, to the customer and to quality), interpersonal skills and appearance 1.4. Reliability of the Provider: consistency of performance and dependability
SOFTWARE (Bai and Sarkis [33], Van Looy et al. [34], Buh et al. [32])	2.1. Software: proprietary simulation software - ease of use, suitability, flexibility, links to third party software, confidence 2.2. Fees: correctly charging for the simulation project
METHODS, MODEL DEVELOPMENT AND DATA INPUT/OUTPUT (Van Looy et al. [34], Buh et al. [32])	3.1. The Model: speed, aesthetics and ease of use 3.2. Confidence in the Model: trustworthiness and believability of the model and the results 3.3. The Data: availability and accuracy
ORGANIZATIONAL CULTURE AND PEOPLE (Bai and Sarkis [33], Van Looy et al. [34], Buh et al. [32])	4.1. Involvement: involving everybody (especially the customer) at all stages of the simulation project 4.2. Education: the customer learns about simulation and the model as the project progresses
COMMUNICATION (Bai and Sarkis [33], Buh et al. [32]	5.1. Communication and Interaction: frequency, clarity and appropriateness of communication and interaction with those involved in the simulation project 5.2. Interpersonal: the relationship between the customer and the provider 5.3. Understanding the Customer: the provider makes every effort to understand the customer's needs and expectations 5.4. Responsiveness: the provider gives a timely and appropriate response to the customer's needs and expectations
TOP MANAGEMENT	6.1. The Customer's organization: the commitment of the customer's organization to the simulation project

SUPPORT AND STRATEGIC ALIGNMENT (Van Looy et al. [34], Buh et al. [32])	
GOVERNANCE (Van Looy et al. [34], Buh et al. [32])	7.1. Recovery: recovering from problem situations 7.2. Access: approachability and ease of contact of the provider; accessibility of the model
OTHER	8.1. Other

Table 6. CSFs framework for DES in BPM projects (sources: Bai and Sarkis [33], Van Looy et al. [34], Buh et al. [32], Robinson [35], Robinson and Pidd, [36])

Table 7 presents the results of our analysis regarding the usage of different CSFs categories as defined in Table 6.

The analysis was conducted based on the 53 papers that explicitly or implicitly report the BPM project success, as identified in the Table 4. First, we have identified the statements that are related to the success of DES in BPM projects. Second, we have coded these statements according the CSFs categories of BPM projects. The second column provides the number of papers that contain at least one statement that reflects the appearance of the CSFs categories of BPM projects. Third column provides the total number of CSF occurrences in the papers. For example, only 4 papers have statements that reflect the impact of the Provider to the success of BPM projects (second column), but in these papers taken together we have identified 7 statements (third column). CSFs were not analyzed for one paper which was not available in English. Fourth column presents the % of occurrences of CSF in papers. For example, 7 occurrences among 143 (4,9%) were related to Provider. Finally, fifth column presents paper ID where the occurrences were found with the number of CSF occurrences in paper (in brackets).

CSFs categories of BPM projects	Number of papers with the CSF category	Total number of CSF occurencies in papers	% of occurences of CSF in papers	Paper ID and number of CSF occurencies in the paper (in brackets)
Provider	4	7	4,9%	6; 7; 14 (3); 17(2)
Software	25	53	37,1%	1(3);2; 3; 6; 8; 9(3); 11; 18(2); 20(4); 25; 27(3); 29(3); 32; 33(2); 35(4); 36; 37; 41(2); 42(3); 43; 44(7); 45(4); 47; 49;50
Methods, model development and data input/output	32	51	35,7%	1(2); 2; 3; 4; 5(4); 6; 7; 10(3); 11; 15;16(2); 18; 19(2); 22; 23(2); 24(2); 27; 28(3); 30(2); 31(2); 36; 37; 39; 40; 41; 42(2); 44; 45; 48; 50; 52(2); 53(3)

Organizational culture and people	12	14	9,8%	6; 12; 13; 19; 21; 24; 27; 32 (2); 40; 44; 46(2); 54
Communication	8	9	6,3%	6; 16; 19(2); 37; 38; 42;49;53
Top management support and strategic alignment	3	3	2,1%	8; 25; 51
Governance	4	5	3,5%	26; 35(2); 49; 53
Other	1	1	0,7%	36
Total	89	143	100,0%	

Table 7. Number of papers with the CSF category and total number of CSF occurrences in papers

The results presented in the Table 7 indicate the following conclusions:

- *Software.* According to the results of analysis simulation software criteria is the most often mentioned (37% of occurencies) as an important factor for project success. The results are quite expected and are well aligned with the previously published studies. According to Tewoldeberhan [39] specific simulation software features such as execution, animation, output analysis and reporting, play very important role in project success. Since a specific knowledge is required to use simulation software Hollocks [40] suggests the introduction of new, additional software functionalities to make simulation software more understandable and acceptable for new users and to ensure its broader application.
- *Methods, Model Development and Data Input/Output.* Close to it is model development, modeling methods, data availability and accuracy (35% of occurencies). The modelling evaluation criteria are related to ease of model building, level of detail, formal semantics and verification of correctness, workflow patterns, resource and data perspective, transparency and suitability for communication [41]. According to Robinson [42] "simulation model development requires more than just the use of software to code the model" while "critical issues lie in the areas of conceptual modelling and validation". When evaluating simulation software features, simulation capabilities and output analysis capabilities of the software are important [41].
- *Organization culture and people.* Organizational culture and people CSF was mentioned in 10% of reviewed papers. According to Diaz [43] there are several aspects of simulation projects that are technically difficult and demanding for project participants, such as: (1) the necessity of having team members who understand not only software development and modeling techniques, but who are also able to understand and synthesize the real-world system being modeled, and (2) communication of a system abstraction to the process owner and / or business champion. A particular emphasis should be placed on the role of simulation sponsor whose main mission is to give support to simulation

activities by disseminating knowledge or information on simulation techniques, as well as the prepare, educate or train users on how to use simulation software [44]. Business experts and researchers recognized the human factors impact in the implementation of DES within a BPM approach such as organizational culture, motivation means and leadership style [45].

- *Communication, provider, governance, top management and strategic alignment.* Communication is ranked next (6%), following with the provider criteria (5%), governance (3%), top management support and strategic alignment (2%) and other (1%). Besides, the analysis of one paper (1%) did not provide applicable results. The lowest ranked CSFs indicate the lack of awareness about the simulation capacity and benefits. The research conducted by Jahangirian et al. [29] showed poor management support and simulation knowledge in the customers' organizations. The results suggest that provider's responsiveness to the customer's needs and expectations holds the association with the overall success of simulation projects. According to Pidd and Robinson [36] the competence of the provider, communication and interaction were very frequently cited as CSFs of great significance for project success. Besides, formal and informal organizational structures should support collaboration and teamwork throughout simulation project.

Table 8 presents the in-detailed description of the statements that occurred in the papers related to different CSFs categories of BPM projects. The implication of the findings above is that simulation-specific CSFs must be taken into account when DES is used in BPM projects. The success is related, though not exclusively, to categories *Software* and *Methods, model development and data input/output*. On the other hand, a series of factors that relate to other categories (Table 8) are very common, so can be applied in almost every BPM project, regardless simulation is used or not.

CSFs categories of BPM projects	The most important issues related to CSFs framework category
Provider	Research papers indicate the following issues related to **provider** that impact the success of BPM project and DES usage: (1) providers use tools they are familiar with; (2) there are not many analysts or consultants that can effectively combine business and network simulation skills; (3) the efficiency of the simulation application crucially depends on the „simulationist" and his/her knowledge about methods, tools and required theoretical basis.
Software	Research papers indicate the following issues related to **software** that impact the success of BPM project and DES usage: (1) the ability to visualize and animate the behavior of the system is the critical issue for the simulation project success; (2) the flexibility of programming language, the capability of modelling complex processes, the speed of simulation and the ability of accurate representation of complex processes are very important characteristics of simulation software; (3) the ability of reporting and exporting simulation results to a desired

	format or program/tool can influence the success of simulation project; (4) user-friendliness and ease-of-use is recognized as a need; (5) other issues, such as: existence of an interface with external modules (e.g. databases), and the ability of a tool for executing simulation models requiring no translation or conversion.
Methods, model development and data input/output	Research papers indicate the following issues related to **methods, model development and data input/output** that impact the success of BPM project and DES usage: (1) a quality of data and the accuracy of model validation is identified as the highest ranked requirements; (2) gathering intelligence from available sources and fitting appropriate distributions to empirical input data influence project results in a positive way; (3) the usage of appropriate methods for validating the model or its output data (e.g. sensitivity analysis, optimization); (4) simplicity of a method in order to allow non-experts to understand, analyze or communicate issues related to logic contained within a model; (5) trustworthiness of the model concerning cost estimations in correspondence with reality; (6) the attention must be turned to aesthetics of the model and model composability issues.
Organizational culture and people	Research papers indicate the following issues related to **organizational culture and people** that impact the success of BPM project and DES usage: (1) education on simulation is important because "if business professionals do not know much about simulations, programming languages, or statistical packages, they cannot ask ad-hoc questions about future outcomes of their business processes"[paper ID 21]; (2) the lack of interactivity between provider and customer can cause the project failure; (3) readiness of organizations to understand and implement the improvements is of great importance.
Communicatio n	Research papers indicate the following issues related to **communication** that impact the success of BPM project and DES usage: (1) incorporating expert opinions in the re-engineering process, seeing simulations "as an effective tool for communication between model developers and users" [paper ID 37] and allowing mutual control by the researcher and client; (2) decomposition of enterprise requirements allows that analysis and understanding of process issues becomes easier.
Top management support and strategic alignment	Research papers indicate the following issues related to **top management and strategic alignment** that impact the success of BPM project and DES usage: (1) management must give support through all phases of simulation project; (2) management must encourage communication so that experts "could contribute their knowledge and information about the processes " [paper ID 19]; (3) readiness of using new optimization algorithms instead of relying on experience and intuition of management can contribute the project success.
Governance	Research papers indicate the following issues related to **governance** that impact the success of BPM project and DES usage: (1) provider's readiness to ensure "flexible data management for updating and extending the model" [paper ID 35] is especially important; (2)

	providers and customers must initiate and support corrective actions for continuous improvement and evolution of the simulation models in use.
Other	Hardware characteristics, technical features, software compatibility and coding aspects can be of relevance for the success of simulation.

Table 8. Description of the statements that relate to the delivery of DES in BPM projects and its success

6. Conclusion

The goal of the paper was to present the results of the systematic literature review of research papers that report usage of DES in BPM projects. The papers (54) were selected from the WoS and Scopus databases that report the case studies of BPM using DES. We have searched the period from 1994 to 2015, using the search based on the specific keywords (business process) AND (discrete AND simulation).

Following conclusions emerge from our analysis. First, the longitudinal trend analysis of the DES reporting in BPM projects (RQ1) revealed that most of the papers were published from 2005 to 2015, which is in line with the research of other authors [19], [20]. Our analysis indicated that the usage of DES in BPM projects is the most often found in Manufacturing and Transportation and storage industries (RQ2), although several case studies were applied in service industries, like Financial and insurance activities. Third research goal (RQ3) focusing to the impact of DES to success of BPM achieved, through the analysis of DES CFSs that were reported as important for BPM project success.

The most important contribution of our study is to present the systematic overview of usage of DES in BPM with the focus on how the authors of the papers report on that issue. Since we have found out that the authors of the papers scarcely and quite rarely report on that issue our future research should focus on defining the standards of DES reporting in BPM.

Limitation of our work stems from the fact that we have focused only to the research papers, while full depth and breadth of BPM case studies using DES could be investigated using other approaches, like action research, and multi case study.

Appendix A: List of selected papers

Paper ID	Paper reference
1	Potter, A., Yang, B., Lalwani, C.: A simulation study of despatch bay performance in the steel processing industry. EUROPEAN JOURNAL OF OPERATIONAL RESEARCH 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. INFORMS JOURNAL ON COMPUTING Volume: 12 Issue: 2 Pages: 125-135, 2000
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Appendix B: CSFs of BPM

CSFs of BPM		
Bai and Sarkis [33]	Van Looy et al. [34]	Buh et al. [32]
Strategic alignment (1)	Modelling: BP analysis (1); BP design (2)	Top management support, management involvement (1)
Top management support (2)	Deployment: implementation (3); measurement and control (4)	Strategic alignment (linkage to organization strategy, alignment of process to organizational goals) (2)
Project management (3)	Optimization: BP evaluation (5); BP improvement (6)	People (capable and motivated employees, training and empowerment of employees, personnel commitment) (3)
Performance measurement (4)	Management: strategy and KPIs (7); external relationships and SLAs (8); roles and responsibilities	Methods, methodology (4)

	(9); skills and training (10); daily management (11)	
User focus (5)	Culture: values (12); attitudes and behaviors (13); appraisals and rewords (14); top management commitment (15)	Communication (5)
Information technology (6)	Structure: organization chart (16); governance bodies (17)	Information technology, technology support, level of IT investments (6)
Culture (7)		Culture, organizational culture (culture of change, culture of collaboration) (7)
Collaborative environment (8)		Project management, change management, project champion (clearly defined objectives, purpose and plan of BPM project; defined roles and responsibilities) (8)
		Performance measurement (measurable results) (9)
		Governance (10)
		Understanding the BPM concept, understanding the process (11)
		Continuous improvement, continuous Optimization (12)
		Clearly defined process owners (13)

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