Journal of Simulation

ISSN: 1747-7778 (Print) 1747-7786 (Online) Journal homepage: https://www.tandfonline.com/loi/tjsm20

Good practices and deficiencies in conceptual modelling: A systematic literature review

Gustavo Teodoro Gabriel, Afonso Teberga Campos, Fabiano Leal & José Arnaldo Barra Montevechi

JOURNAL OF SIMULATION
https://doi.org/10.1080/17477778.2020.1764875

Good practices and deficiencies in conceptual modelling: A systematic literature review

Gustavo Teodoro Gabriel, Afonso Teberga Campos, Fabiano Leal and José Arnaldo Barra Montevechi

Federal University of Itajubá, Itajubá, Brazil

ABSTRACT

Conceptual modelling is a continuous and iterative process that is essential for simulation projects. However, it often does not receive due consideration. In this sense, many projects document and/or perform the conceptual modelling without following good practices, which ends up affecting the next stages of the simulation. This work aims to identify the state of the art and patterns of conceptual modelling through a Systematic Literature Review (SLR), especially regarding the articles' adherence to good practices. We identified 13 good practices for conceptual modelling in the literature, which aims to develop effective conceptual models, i.e., models with suitable syntactic, semantic, and pragmatic quality. The results of the SLR indicate that although some good practices are consolidated, others need more attention, especially regarding semantic, pragmatic and report quality. Finally, we establish future directions to guide and improve projects that use conceptual modelling.

ARTICLE HISTORY
Received 28 September 2019
Accepted 1 May 2020

KEYWORDS
Conceptual modelling; simulation; systematic literature review

1. Introduction

Computer simulation is the reproduction of a process using a computer model to evaluate, measure and improve its performance (Harrell et al., 2012), be it hypothetical or real, and is commonly applied to perform experiments (Negahban & Yilmaz, 2014). In the literature, we can find studies about Discrete Event Simulation (DES), in which the variables change instantly in a given time span (Garani & Adam, 2008; Yuriy & Vayenas, 2008); Continuous Simulation or System Dynamics (SD), which take into account systems that change continuously over time and are considered continuous processes (Bureš, 2015); Agent-Based Simulation (ABS), which involves autonomous agents observing unexpected patterns of system behaviour, capturing their interactions and being governed by rules (Macal & North, 2014; Mgbemena & Bell, 2016); and Hybrid Simulation (HS), which is the combination of two or more types of simulation that act together to solve a problem that cannot be figured out with one of these individually, complementing the strengths of each one (Djanatliev & German, 2013; Wang et al., 2015).

One of the first efforts in a computer simulation project is conceptual modelling (CM). CM is the abstraction of a model from the real system and indicate what and how it should be modelled (Fayoumi & Loucopoulos, 2016; Furian et al., 2015; Robinson, 2008). The abstraction is the simple form of representation (Robinson, 2013). The conceptual model is a graphical or logical representation of a particular study without using any software (Robinson, 2008; Sargent, 2013). It should include content such as structure, behaviour, constraints, and assumptions (Karagöz & Demirörs, 2011; Robinson, 2008). In addition, although CM may be performed just mentally, we often find conceptual models' formal representations (documentation), which are recommended (Robinson et al., 2015).

There are several advantages to using CM in computer simulation projects. CM allows a more straightforward implementation of a computer model and, when developed correctly, decreases project time and improve the simulation quality (Da Silva et al., 2014; Francisco et al., 2016; Zhou et al., 2006). Besides, it facilitates project data collection and management (Banks et al., 2010) and behaves as a means of communication between all parties involved in the study (Pace, 2002). Therefore, CM should receive special attention.

However, if projects do not carry out proper CM, they may a stray from the initial goal of the study; validation becomes weak, and the model may lose its usefulness, leading to possible rework (Squires et al., 2016). These problems are not uncommon, 25% of modellers have already reworked non-realistic conceptual models (Wang & Brooks, 2015). In fact, CM is the least understood step in the simulation process and receives less attention than is ideal (Montevechi et al., 2010; Wang & Brooks, 2007).

CONTACT Gustavo Teodoro Gabriel gustavo.teodoro.gabriel@gmail.com Industrial Engineering and Management Institute, Federal University of Itajubá, Av. BPS, 1303, Itajubá/MG 37500-903, Brazil

It is possible to overcome problems that appear in the CM process by defining and adopting good practices (GP) for CM. Although it is challenging to define methods and procedures to be followed, (Robinson, 2011) and (Lindland et al., 1994) listed some GPs to improve the quality in CM. The authors suggest, for future work, a deepening discussion on both quality dimensions and means to achieve them. Since then, several works have aimed to discuss GPs for CM (Banks, 1998; Chwif & Montevechi, 2015; Koivisto, 2017; Lindland et al., 1994; Overmyer et al., 2001; Pace, 2000; Robinson, 2008, 2015; Robinson et al., 2015; Roca et al., 2015; Tako & Kotiadis, 2015; Williams & Ülgen, 2012), creating a fragmented literature on the subject. To our best knowledge, there are no papers that consolidate, discuss, and organise these practices. Furthermore, by consolidating such practices, the opportunity arises to explore the relationships between them, in particular, to assess how they are mutually supported. For these reasons, this article aims (i) to identify in the literature GPs for CM, consolidating and discussing them; (ii) identify the state of the art of CM in computer simulation projects, especially regarding their adherence to the GPs through a Systematic Literature Review (SLR); and (iii) evaluate deficiencies and means to overcome them. This paper uses the following organisational structure: Section 2 discusses the GPs found in the literature; Section 3, the SLR method; Section 4, the results; Section 5, the discussions; Section 6, future directions; and, finally, in Section 7, the conclusions.

2. Good practices for conceptual modelling

The GPs (framework) aims to obtain effective conceptual models, i.e., models with proper levels of syntactic, semantic, and pragmatic quality, defined by (Lindland et al., 1994). Syntactic quality is the degree to which the model is consistent with the language syntax, i.e., its alphabet (set of modelling elements) and grammar (rules that define how to combine modelling elements). The more errors and deviations from the modelling alphabet and grammar, the lower the syntactic quality. Semantic quality is associated with the meaning of a word, phrase or expression in a given context (Zeigler & Hammonds, 2007). Moreover, semantic quality is the degree of similarity between the conceptual model and the system's own (Krogstie et al., 1995; Lindland et al., 1994) understanding of how real the message is transmitted (Zeigler & Hammonds, 2007). If the model lacks something that the system has or something that the system does not contain, the semantic quality becomes worse. Finally, pragmatic quality is the audience's degree of model comprehension. Modellers should ensure that all concerned parties entirely understand the relevant statements in the model. These quality dimensions are

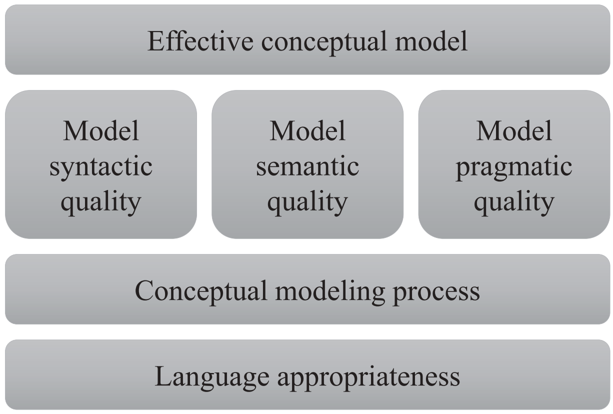

Figure 1. Framework of GP.

ideal goals. Frequently, we cannot include everything that the system has or develop a model that everyone will completely understand. For this reason, modellers should consider a trade-off between the benefits and costs of achieving a certain quality level.

In order to achieve proper levels of these quality dimensions, our framework comprises a set of GPs found in the literature and related to the conceptual modelling language, process, and conceptual model characteristics. It does not list GPs but explores the synergies between them, thereby enabling modellers to identify GPs that support other GPs and therefore should be considered first. The framework (Figure 1) has two foundations: the modelling language appropriateness and the conceptual modelling process. The GPs related to these foundations support specific practices focused on the three quality dimensions, which are the pillars of an adequate conceptual model.

The proposed framework was based on the characteristics mentioned by (Lindland et al., 1994) and (Krogstie et al., 1995). Firstly, language appropriateness is the basis for understanding the system and its documentation. In this sense, the first characteristic is the ideal language choice. As the second base, we adopted the use of a conceptual modelling process that supports the development of good characteristics for the conceptual model. These characteristics, explored by (Lindland et al., 1994) and (Robinson, 2008), are related to the correct use of the chosen language (syntactic quality), adequacy of the documentation to reality (semantic quality), and the final understanding of the modelling and documented system (pragmatic quality). Each of these quality dimensions can be reinforced through specific recommendations, which will be detailed in this paper. Thus, by modelling the system using the two bases and the three qualities mentioned above, it is possible to obtain an effective conceptual model.

2.1. *Language appropriateness*

The conceptual modelling language appropriateness impacts both the CM process and the CM qualities as (i) modellers should have suitable proficiency levels in the chosen language, avoiding errors that decrease the conceptual model syntactic quality; (ii) the language should be appropriate for the system that will be modelled, facilitating the inclusion of essential elements for its representation and, consequently, helping to improve the model semantic quality; and finally, (iii) the audience should have proper knowledge of the chosen language, which impacts their comprehension of the model and therefore its pragmatic quality. In this sense, we identified four GPs for the CM language choice presented in Table 1.

2.2. Conceptual modelling process

The second foundation is the conceptual modelling process, comprising three GPs that support all quality dimensions. Many authors state the artistic (Robinson, 2008), cyclical (Banks, 1998; Robinson, 2008), and iterative (Robinson, 2008, 2015) nature of this process (we agree), rather than making it rigid, the defined GPs still allow flexibility (Table 1).

The modeller should continually evaluate validity, completeness, and understanding with the audience feedback and, if possible, the observation of the modelled system. On the other hand, the verification of the syntactic correctness is usually an activity carried out only by the modeller. In addition, it may be performed in the later stages of the modelling process, allowing modellers to dedicate more time and effort to the model content at early stages.

2.3. Syntactic quality

As noted earlier, the main characteristic of this quality dimension is the adequacy to the alphabet and the grammar of the chosen language (Table 1).

2.4. Semantic quality

Generally, it is not necessary to insert all the elements and characteristics of the system to achieve the project scope, but only those that are relevant to the project. For this reason, modellers should try to obtain appropriate levels of semantic quality to the application context, seeking to add all relevant information, which leads to the next GP (Table 1).

2.5. Pragmatic quality

Finally, GPs related to the pragmatic quality aim to support the audience's understanding, indicate a need for conceptual models that are visually appropriate, connected with other relevant information, and unbiased towards the chosen simulation software (Table 1).

3. Research methodology

Systematic Literature Reviews aim to integrate empirical research by creating generalisations since it is a scientific methodology that goes beyond a simple overview of a given subject (Biolchini et al., 2007). It provides support for research guidelines about the selection, evaluation, and analysis of the chosen studies. Additionally, analyses of the collected results can be both qualitative and quantitative, contributing to answering the proposed questions (Cook et al., 1997; Tranfield et al., 2003). SLR comprises three stages: planning, executing and describing the results (Kitchenham & Charters, 2007).

3.1. Planning

We evaluate the need for an SLR and define the research questions. For this, two experts in the simulation area analysed CM in recent research studies. As a search result, we have found studies that try to bring together definitions, applications and validation techniques of CM in simulation projects from other authors (Ding & Sun, 2014; Liu et al., 2011; Wang & Brooks, 2015; Zou et al., 2016). Furthermore, we have found reviews that present the GPs in a fragmented form as mentioned in the introduction. Nevertheless, these papers do not identify adherence to GPs (main paper's contribution). In this sense, we defined the research question:

Q1: Are good practices for conceptual modelling (as defined in section 2) adopted by simulation projects?

Moreover, if possible, the SLR should identify patterns followed in the articles.

3.2. Execution

The research was carried out on February 1 2017, in the largest available databases (Alrabghi & Tiwari, 2015): *Scopus, Science Direct*, and *Web of Science*. We used four groups of terms to search for articles. These terms could be in the title, abstract or keywords. An "*OR*" Boolean operator was used for words that are between the same group and an "*AND*" operator between groups. The research period comprises 15 years (2002–2017). Figure 2 shows the terms searched in the databases.

We chose to search for terms that highlight the use of CM in their studies. In this way, we found 236 articles in *Scopus*, 35 in *Web of Science*, 62 in *Science Direct* and 25 related to other sources, totalling 358. Of those, 31 articles were duplicates. Thus, 327 articles moved on to the title and abstract reading stage.

In this step, we performed a peer-review process. Two experts read the title and abstract and decided, separately, if the article should be kept for further analysis. With this approach, the risk of losing

Table 1. Classification of GPs.

Characteristic	Good Practice	Authors
Language appropriateness	1) Choose a conceptual modelling language consistent with the audience's knowledge or ability to learn, which promotes the pragmatic quality	Lindland et al. (1994).
	2) Choose a conceptual modelling language appropriate for the application (e.g., system characteristics and complexity, and type of simulation), which benefits the semantic quality	Lindland et al. (1994), Pace (2000).
	3) Choose both a textual and a visual language. Diagrams are usually easier to understand and should be preferred. However, additional texts may support the understanding, if the audience is unfamiliar with the visual language, improving pragmatic quality and if the diagrams are not able to incorporate all the relevant information, enhancing semantic quality.	Lindland et al. (1994), Overmyer et al. (2001), and Robinson (2015).
	4) Choose a language that facilitates the conceptual model translation into the computer model, allowing the inclusion of necessary information through specific visual elements for entities, locals, functions, resources, control rules, and connections. Thereby, this good practice helps to improve semantic quality.	Banks (1998), Lindland et al. (1994), Pace (2000), and Robinson et al. (2015).
Conceptual Modelling Process	5) Involve the client and the project team in the conceptual modelling process. This practice helps (i) to promote knowledge sharing and inclusion into the model, improving semantic quality; and (ii) to improve pragmatic quality as the client becomes familiar with the conceptual model not only in the advanced stages of the modelling process but during its entire development.	Banks (1998), Lindland et al. (1994), Robinson (2008), Robinson (2015), Robinson et al. (2015), Tako and Kotiadis (2015), and Williams and Ülgen (2012).
	6) Develop the model from the simplest details to the most complex ones, which (i) helps to choose the appropriate model complexity level for the application; (ii) allows a progressive validation process; and (iii) together with the good practice of client and project team involvement, supports the comprehension development, avoiding understanding difficulties with models already complex. With these benefits, this good practice enables the improvement of semantic and pragmatic quality.	Banks (1998), Koivisto (2017), Lindland et al. (1994), Pace (2000), Robinson (2008), and Robinson et al. (2015).
	7) Review the conceptual model during the entire modelling process, verifying (i) the syntactic correctness, which promotes syntactic quality; (ii) the validity (if existing errors in the model are within an acceptable limit) and completeness (if the lacking information is within an acceptable limit), which helps to improve semantic quality; and (iii) the audience's understanding of the model, i.e., the pragmatic quality.	Banks (1998), Lindland et al. (1994), Pace (2000), Robinson (2008), Robinson et al. (2015), and Roca et al. (2015).
Syntactic Quality	8) Adopt the rules of the chosen conceptual modelling language. It is possible to find visual language specifications and guidelines that can support this good practice, e.g., for BPMN, IDEF-SIM (Montevechi et al., 2010), and flowchart (Rossheim, 1963). Moreover, this good practice assists in understanding the model (i.e., pragmatic quality), since the audience does not need to comprehend symbols and rules which are incorrect and, possibly, unusual and challenging to interpret.	Lindland et al. (1994).
Semantic Quality	9) Choose a level of detail appropriate for the purpose of the project, considering the scope of the application, project questions, objectives and metrics.	Banks (1998), Lindland et al. (1994), Pace (2000), Robinson (2008, 2015); Robinson et al. (2015), and Roca et al. (2015).
Pragmatic Quality	10) Avoid visual pollution. While the good practice nine is concerned with an information balance between system and conceptual model, avoiding the inclusion of irrelevant and low-value information, this good practice aims to obtain clean and easy to read conceptual models, avoiding excessive, redundant, and confused visual information. It is essential to keep the elements well organised and to use short and non-overlapping connections.	Chwif and Montevechi (2015).
	11) Explain adopted simplifications and assumptions, helping the audience to understand the degree of abstraction of the model.	Banks (1998), Robinson (2008), and Robinson et al. (2015).
	12) Develop a conceptual model that is integrated with external data, presenting hooks or references to complementary data such as tables, images, and other conceptual models (Banks, 1998).	Banks (1998).
	13) Develop a conceptual model that is as neutral as possible in relation to the simulation software that will be used. It means that modellers should avoid adapting the conceptual model to specific features or characteristics of the simulation software such as artifices and workarounds often used for programming, transforming the conceptual model into a computer model specification. Otherwise, the audience, in addition to having to understand the language and the model, will have to understand the characteristics of the software and computer modelling strategies. The modeller may create a computer model specification that covers this additional information, but this should be kept separate.	Pace (2000), Robinson (2008), and Robinson et al. (2015).

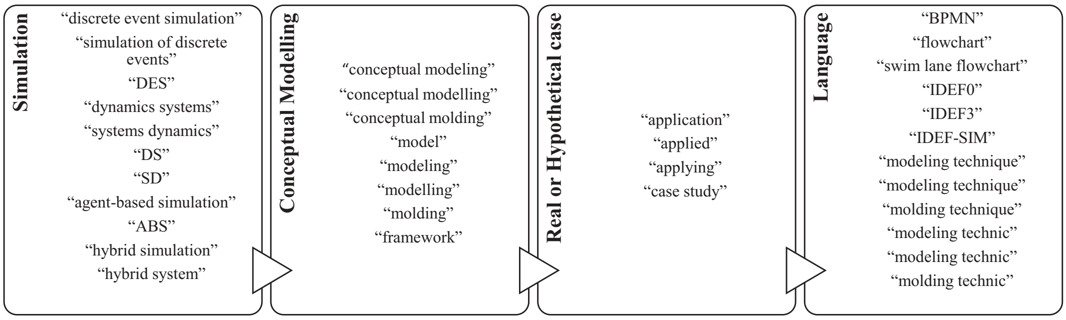

Figure 2. Groups of terms for searching.

information is significantly lower than with just an individual review (Edwards et al., 2002). We included only computer simulation projects that present a conceptual model (diagram).

We used Cohen's Kappa to evaluate the agreement between the two experts (Landis & Koch, 1977). Values close to 1 show perfect agreement, and values close to zero suggest that the agreement represents the same as if it were performed at random (Watson & Petrie, 2010). We divided the articles into subgroups of size 20 and analysed them separately. Thus, when closing the analysis of each subgroup, the concordance test was performed. For the present study, Kappa values above 0.60 were defined as acceptable. If the test had values below 0.60, specialists should identify the disagreement causes. In our test, we found only two subgroups presenting Kappa values below 0.60, and only slightly. Thus, the articles' inclusion and exclusion criteria were well defined among the evaluators. The experts agreed on 92.35% (302) of the articles.

After the article-screening phase, we excluded 222 articles, passing 105 to the reading phase. In this phase, 27 articles were excluded: 10 did not present a conceptual model; 10 were not available in databases; 4 used another type of simulation different from the pre-defined; 2 did not present an application; and one was in a different language from the authors' knowledge. In this way, 78 articles proceed to qualitative synthesis and data analysis. Figure 3 shows the SLR procedure.

3.3. Description

The last phase relates to the analysis results and description. Appendix presents the collected and summarised data. Sections 4 and 5 present the results and discussion, respectively.

4. Results

This section aims to present an overview of the CM stage found in the analysed studies. Of the publications, 69.2% (54) of the papers were academic journal publications and 30.8% (24) were articles from conferences. Among the articles, 51.3% (40) state that CM is an important step. The other 48.7% (38) use it, but they do not emphasise the importance of this stage in a computer simulation.

As previously mentioned, we delimited the research to the last 15 years. Since 2002, the use of the CM stage in simulation projects has not shown any significant tendency (p-value = 0.138). Although computer simulation has been growing over the years (Banks et al., 2010), articles evidencing CM do not follow the same trend. This result supports previous studies that indicate that CM stage receives less attention than the ideal (Montevechi et al., 2010; Wang & Brooks, 2007).

Moreover, 50.0% (39) of the articles applied DES as a computer simulation tool, while 26.9% (21) used SD. Only 10.3% (8) used ABS, which may be related to the fact that this simulation type is more recent. Finally, we found HS in 12.8% (10) of the cases. These results are consistent with those presented by (Jahangirian et al., 2010) and (Alrabghi & Tiwari, 2015). Among the HS projects, we found more studies with DES and ABS, 40.0% (4), presented in manufacturing systems (Liraviasl et al., 2015; Schönemann et al., 2015). For hybrid models of SD and ABS, we identified studies in healthcare (Martischnig et al., 2009), military conflicts (Geller & Alam, 2010), and manufacturing (Choong & McKay, 2014), totalling 30.0% (3). The combination of DES and SD has 20.0% (2) of articles, in such fields as healthcare (Zulkepli & Mustafee, 2012) and civil construction (Moradi et al., 2015). The other 10.0% (1) are the combination of other simulation types (Hennemann & Rabelo, 2006).

In the literature, the studies use many languages for the CM stage. Some of them present rules, such as Causal loop, Flowchart, IDEF-SIM, BPMN, IDEF0, IDEF3, among others. In our findings, 28 studies used other languages that do not present predefined symbols or use images to represent the process e.g., (Pehrsson et al., 2013) and (Sajjad et al., 2016). We designated this language as "Flow". Other studies found similar results in the literature (Wang & Brooks, 2015). Furthermore, in the SLR, we detected more expressive languages: Flowchart (Babashov et al., 2017; Dong et al., 2012), IDEF-SIM (Francisco et al., 2016; Pereira et al., 2015), flow, and causal loop (An et al., 2007; Garousi & Pfahl,

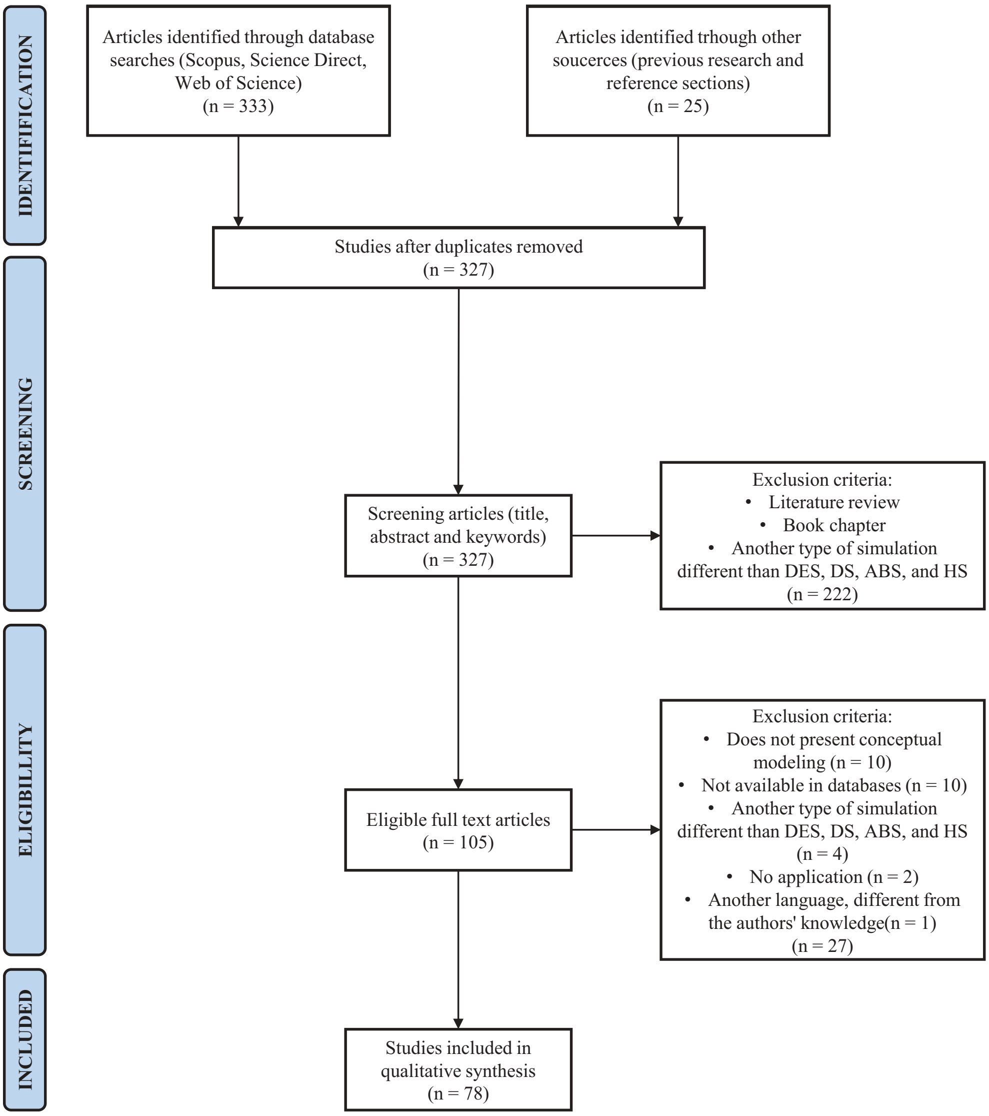

Figure 3. SLR data flow.

2016). They represent 79.5% of all used modelling language. Other languages still appeared, but with less representation, such as BPMN (Onggo, 2012), CYCLONE (Flood, 2015), IDEF0 (Martinez-Olvera, 2007), IDEF3 (Bevilacqua et al., 2015), and VSM (Abdulmalek & Rajgopal, 2007). However, it is not the purpose of this paper to discuss in detail the characteristics and syntax of each language.

5. Discussion

This section aims to discuss how the analysed studies are using the GPs defined in section 2. It is not possible to identify the adherence to all GPs in the selected articles though in the SLR process we were able to verify that many of them were followed.

5.1. GP1: Audience's knowledge

The first GP is related to the comprehension and level of relationship between modellers and their clients. The language used should be easy to understand for both parties. The conceptual model is the basis of a simulation project and it is considered a means of communication for all the elements involved in it (Liu et al., 2011; Pace, 2002). A compatible language between the two parties supports easier understanding and validating. Although it is an essential GP for the beginning of CM, it is not possible, through reading the studies, to identify if the language used for CM was adequate for the audience.

5.2. GP2: Application

The appropriate language for an application is a language connected to the type of computer simulation (DES, SD, ABS or HS) and the system domain. Often, if the process is simple, languages that do not require a sophisticated syntax may be used to represent the system. However, if the processes are complex, complete languages should be applied.

We observed that ABS and HS are associated with Flow language, although others are used. Besides, causal loop combined with stock and flow diagram is the predominant language for SD. On the other hand, many languages are associated with DES, excepting causal loop and stock and flow diagram. This may indicate that DES is applied to several domains and different system complexities, requiring languages that are suitable for each of them.

5.3. GP3: Textual and visual language

Using texts for CM facilitates the process comprehension if the audience does not know the syntax of a particular language. In this way, the modeller may describe the process as a text (Wang & Brooks, 2007). In the analysed studies, 78.2% (61) described the simulated process through text and used diagrams. Some studies use the text since the system is complex and requires a deeper knowledge for its comprehension (Gaion et al., 2009; Heeg et al., 2005). On the other hand, 21.8% (17) do not use texts as support.

Moreover, the text explains the necessary elements for the model conversion into computer modelling, such as entities, resources, and locations. Authors used this element to explain elements of their processes (Hou, 2013; De Rangel & Nunes, 2011).

5.4. GP4: Translation from the conceptual model to the computer model

The language used in CM should have a syntax that allows a direct translation to the computer model in order to reach the project objective (Montevechi et al., 2010; Pereira et al., 2015). The language symbols may be entities, sources, functions, connections, logical rules, transport, and handling.

We evaluated the diagram support for translation to the computer model as good, regular, or poor. Diagrams with good support feature the applicable and necessary elements for the translation of the conceptual model to the computer model. Regular are those diagrams that have part of the necessary elements and may use workarounds to complete their total translation. Finally, poor diagrams only present functions and process connections.

Considering the analysed articles, 65.4% (51) presented diagrams with good support. These diagrams used languages such as BPMN (Bisogno et al., 2016), IDEF3 (Bevilacqua et al., 2015), IDEF0 (Martinez-Olvera, 2007), and state diagram (Liraviasl et al., 2015), identified as facilitators in the translation of DES, ABS and HS models. Furthermore, IDEF-SIM was considered an important language that offers logical elements for DES systems modelling (Montevechi et al., 2010; Pereira et al., 2015) and causal loop and stock and flow diagram for the iterations present in SD (Lin et al., 2015; Perez-Mujica et al., 2014). The use of causal loop and stock and flow diagram for SD, reinforced in these studies, explains the pattern found in the analysis of GP2.

Usually, articles that have diagrams with regular support use generic and simplified schemas for the process representation. These totalled 24.4% (19) of the studies. Despite this, we observe some elements that are necessary for translation into the computer models, such as assumptions (Choong & McKay, 2014), entities, locals, and resources (Sharda & Bury, 2011). Finally, 10.2 % (8) of the studies present poor diagrams, using only drawings (Dundović et al., 2009) or the process flow with functions and connections (Li et al., 2014).

5.5. GP5: Client and the project team

Involving the client and the team throughout CM is of great importance since the customer is an essential part of a simulation project. Stakeholders and the modellers may present multiple perspectives on a process and this interaction contributes to finding possible solutions (Tako & Kotiadis, 2015). Furthermore, if the client is involved from the beginning, there is more chance that it will be understood and that the choice of the language will be more effective. Additionally, the client's involvement makes the process data sufficient to understand the elements that the modeller will represent (e.g., number of resources, probability of routing) (Ramwadhdoebe et al., 2009).

In our findings, 74.4% (58) of the articles did not describe the CM process. For this reason, we cannot infer if these papers followed this GP. Despite using CM in the simulation projects, few authors demonstrated how it was performed, which is considered a deficiency. However, the remainder, 25.6% (20), did describe it or at least indicated that there were interviews with people who know the process (Agyapong-Kodua et al., 2012; Mahato & Ogunlana, 2011) or technical visits at the site (Bisogno et al., 2016).

In processes performed in hospitals, the modelling team involves doctors, nurses, and receptionist staff (Baril et al., 2016; Stainsby et al., 2009). For manufacturing process, stakeholders, plant managers, and production line staff were part of the team for better system comprehension (Atieh, Kaylani, Almuhtady, & Al-Tamimi, Sandanayake et al., 2008).

5.6. GP6: From the simplest to the most complex details

This GP aims to prevent the modeller from getting lost in the construction of complex processes. If the process and project goal require more meaningful details, we recommend starting from macro processes. Details that are specific to particular points should be added as they are deemed relevant. We cannot identify this GP in the studies since most of them do not demonstrate the execution of CM.

5.7. GP7: Review

Reviewing the conceptual model throughout the process is of great importance for the communication between the audience and the modellers. Moreover, the cyclic review allows us to identify errors that occur during the construction of the model. In the study carried out by (Merrill et al., 2013), the conceptual models were constructed and presented to experts. After discussions and revisions, the experts participated in a new cycle in order to verify the model accuracy. If there were still differences, discussions would continue until all questions were answered.

Validation is an essential step in a simulation project (Francisco et al., 2016) since it is the basis for other steps. The most classic and effective technique is face-to-face validation (Sargent, 2013). The conceptual model is presented to the specialists and staff, who understand, participate or work in the real process. Then, experts say if the model reflects the actual process. Through SLR analysis, 21.8% (17) studies show that the model was validated using the face-to-face technique (Kashimbiri et al., 2005; Perez-Mujica et al., 2014). In one of these studies, the conceptual model was validated by showing it to people working in the same environment as the real system, but not directly related to it (Montevechi et al., 2007). The other studies do not describe the conceptual model validation. In general, there is a more significant concern to demonstrate computer model validation.

5.8. GP8: Language's rules

It is necessary to choose a language in which the modeller is proficient since misuse can cause future reworking and misunderstanding by the audience. In this sense, the conceptual model must obey the syntax (rules) that a language has. We did not evaluate all studies for this GP because of the large number of identified languages. Moreover, we ae not experts in all languages presented in the studies. However, it is possible to point out some diagrams with syntax errors, i.e., errors related to the incorrect use of symbols representing locations, entities, resources, controls, and how the elements are connected (using arrows) in the system representation.

5.9. GP9: Level of details

CM detail level is directly related to the project's purpose and objectivity. Complex projects require a more specific level of detail to each point. This GP is related to GP6, which recommends starting the CM from simple details to the more complex ones. Although relevant, we cannot evaluate this GP in the identified papers, since it is not possible to have access to the modelled systems.

5.10. GP10: Visual pollution

We observed examples of flows considered clean and with adequate information in hospitals (Pecek & Kovacic, 2011), services (Garousi & Pfahl, 2016), and transport (Elbanhawy et al., 2014). On the other hand, other studies present an excess of information (Sousa et al., 2005) and even graphic elements that overlap (Yang & Liyi, 2011), leaving the model visually polluted.

For this, we classify the level of organisation of graphic elements and the visual present in the models into three categories: good, regular, and insufficient. In the "good" category, models avoid long connections and overlapping. Thus, the comprehension of the process does not become confusing. The "Regular" category includes diagrams that have either long connections or overlapping. Finally, the "insufficient" category comprises articles that present conceptual models with both long connections and overlapping between them.

Most of the evaluated models, 67.9% (53), were classified as good (Bublitz et al., 2014; Sobolev et al., 2008). In general, we can observe an organisation that allows us to read the models linearly. Additionally, the connected elements are close, avoiding overlapping between the connections. Next, 21.8% (17) were classified as regular, presenting either very distant connected elements (Atieh et al., 2016) or overlapping connections (Clouth et al., 2010). Finally, we founded insufficient diagrams in 10.3% (8) of models, which have long spacing between functions and overlapping joints. Some articles that used causal loop and stock flow language were classified into this category (Orji & Wei, 2015; Walton et al., 2009) since there is much information and a lot of relationships that cross-over, which harms the organisation and the visual of the conceptual model. However, this is a characteristic of the language, and, frequently, it is not possible to prevent this. Projects that used a language of their own (Gagliardi et al., 2014; Karnon, 2003) or even languages with defined rules (Hennemann & Rabelo, 2006) also presented insufficient organisation concerning site spacing and cross-connections.

5.11. GP11: Simplifications and assumptions

Simplifications are necessary to make the model faster and easier to use. Assumptions are required to address the necessary uncertainties and missing data (Robinson, 2008). In particular, it is necessary to simplify relations or details that will not contribute to the conversion of the conceptual model to the computer model. This GP cannot be identified through the articles, because it is difficult to identify the assumptions and simplifications made during CM.

5.12. GP12: Integrated conceptual modelling

External data help in the comprehension of the process and prevent the conceptual model from becoming visually polluted, contributing to GP10. A good representation of external data is a table. We identified examples of tables integrated to the conceptual models to indicate figure legends (Topping & Odderskaer, 2004), numerical data (Zupan & Herakovic, 2015) (e.g., processing time, flow probability, number of resources), necessary information for the simulation (Nicolae et al., 2010), and details of the flow (Huirong & Xiaoning, 2010; Sahaf et al., 2014).

5.13. GP13: Neutral conceptual model

CM must be performed independently of the software used in the computer simulation since its construction is the abstraction of the real process (Robinson, 2008). One of the reasons is that CM may be performed only for process mapping. It is not possible to evaluate this GP since it would require a thorough knowledge of all software found in the articles. In fact, 24.4% (19) of the 78 reviewed articles did not mention which software was used. In total, 29 software were found: Arena® (11.5%), ProModel® (7.7%), AnyLogic® (7.7%), VenSim® (6.4%), Ithink® (3.8%) and Simul8® (3.8%). We observed that AnyLogic® (5 studies) is usually linked to SHY.

6. Future directions

We have established future directions to guide future works. In this sense, we classify the GPs found in the literature and identified in the papers in two categories: objective or subjective and support/required or improvement/optional.

GPs classified as objective do not depend on the modeller's interpretation to be used. Contrarily, GPs classified as subjective are those in which the modeller decides how to carry them out based on his knowledge and perception. Included in the support/required category are those GPs that are important and are the basis for other stages in the simulation process, avoiding reworking and serving for further verifications (Squires et al., 2016). Practices allocated into the improvement/optional category help the conceptual model to be cleaner and easier to understand, improving its final quality. These practices may be carried out or not according to the complexity of the project. Table 2 presents the 13 GPs classified.

As Table 2 shows, GPs 2, 4, 6, 9, 10, 11, and 13 are subjective and may be implemented according to the modeller's perception. In these GPs, the modeller may make decisions according to his expertise, such as choosing the language that is most appropriate for the desired application; the level of detail; simplifications and assumptions made, among others. Other GPs are classified as objective because they are directly implemented.

For the second classification, GPs 1, 2, 5, 7, 8, and 9 are defined as support/required. These GPs should receive more attention in the conceptual model construction and should be present in all the projects that use it as a basis for the simulation project. On the other hand, GPs 3, 4, 6, 10, 11, 12 and 13 were classified as improvement/optional. Although these GPs help to improve quality and facilitate the conceptual model construction and reading, they should be taken into account according to the specification of each project.

Still, depending on the project, the choice of some GPs may interfere or even make it impossible to choose others. In such cases, the modeller should consider what GP is most important in the project context. Table 2 shows that, e.g., choosing GP1 may restrict the choice of language appropriate for the application and the choice of a language that facilitates the translation for computer modelling. This may occur if the audience does not have an ideal knowledge of the language for the project carried out. There are two groups of recommendations that may be restricted to this classification. The first includes GPs related to language appropriateness and audience involvement. The second group is formed by GPs linked to the semantic and pragmatic qualities, more specifically related to the trade-off between model completeness and visual pollution. In the same way, the GP choice may negatively affect the quality of another, e.g., the model may present a good visual quality but harm the level of system detail and simplifications and assumptions. When this happens, it is up to the modeller to decide which GP should be prioritised and which will least affect the final quality of CM documentation.

Based on the SLR, Table 2 presents GPs that are already consolidated in the literature (followed in more than 60% of the studies):

2) Choose a conceptual modelling language appropriate for the application. There is a strong association between the language used and the application type (p-value <0.001);

3) Choose both textual and visual language. In the evaluated projects, 78.2% (62) used both languages in order to model the system;

4) Choose a language that facilitates the conceptual model translation into the computer model. Considering the articles, 65.4% (51) presented good diagrams and 24.4% (19) with regular support. Although we considered it a consolidated practice, modellers should pay more attention to the

Table 2. GP categories.

Good practice	Objective	Subjective	Support/ Required	Improvement/ Optional	Trade-off	Consolidated
1) Choose a conceptual modelling language consistent with the audience's knowledge or ability to learn.	✓		✓		2, 4	-
2) Choose a conceptual modelling language appropriate for the application.		✓	✓		1, 4, 5	✓
3) Choose both a textual and a visual language.	✓			✓	-	✓
4) Choose a language that facilitates the conceptual model translation into the computer model.		✓		✓	1, 2, 5	✓
5) Involve the client and the project team in the conceptual modelling process.	✓		✓		-	-
6) Develop the model from the simplest details to the most complex ones.		✓		✓	-	-
7) Review the conceptual model during the entire modelling process, verifying (i) the syntactic correctness; (ii) the validity and; and (iii) the audience's understanding of the model.	✓		✓		-	-
8) Adopt the rules of the chosen conceptual modelling language.	✓		✓		-	-
9) Choose a level of detail appropriate for the purpose of the project.		✓	✓		10	-
10) Avoid visual pollution.		✓		✓	9, 11	✓
11) Explain adopted simplifications and assumptions.		✓		✓	10	-
12) Develop a conceptual model that is integrated with external data, presenting hooks or references to complementary data.	✓			✓	-	-
13) Develop the conceptual model that is as neutral as possible in relation to the simulation software that will be used.		✓		✓	-	-

construction to clarify and facilitate the model translation. We recommend avoiding the use of own languages (flow) because commonly they are not sufficiently structured to contain the necessary information;

10) Avoid visual pollution. This practice is consolidated in the literature since 67.9% (53), and 21.8% (17) of the studies were classified as good and regular, respectively. However, there is still room for improvement. We identified diagrams that have long connections and/or overlapping, characterising a deficiency of pragmatic quality. When possible and applicable, we recommend organising the model in a linear form and avoiding excessive information.

Through the SLR, it is also possible to observe GPs that are not consolidated in the literature:

5) Involve the client and the project team in the conceptual modelling process. This practice is directly linked to GP1. In our study, only 25.6% (20) of the articles described or at least indicated that there were interviews with the people who know the process;

7) Review the conceptual model during the entire modelling process. Only 21.8% (17) studies show that the model was validated. In general, there is a more significant concern to demonstrate computer validation. This practice needs improvements to avoid model rebuilding;

8) Adopt the rules of the chosen conceptual modelling language. This GP may be considered consolidated if the modeller has previous knowledge of the language used. We recommend choosing a language that is already known in order to avoid errors and possible confusion in future stages of the project;

12) Develop a conceptual model that is integrated with external data, presenting hooks, or references to complementary data. According to our findings, only 19.4% (14) of studies present an integrated model with external data.

Moreover, we identified a significant deficiency in report quality regarding CM. We recommend that future studies develop and use a protocol that indicates the relevant information of the CM process that should be included in the reports. In particular, we recommend inserting information such as level of involvement between the team and the client and CM process validation. For this reason, many of the GPs could not be assessed. In this sense, GPs that could not be measured:

1) Choose a conceptual modelling language consistent with the audience's knowledge or ability to learn. This GP is essential since it is the integration of team members and it supports other phases. Although many studies do not report this choice and interaction between the parties, we recommend using a language that all the members know.

6) Develop the model from the simplest details to the most complex ones.

9) Choose a level of detail appropriate for the purpose of the project.

11) Explain adopted simplifications and assumptions.

13) Develop a conceptual model that is as neutral as possible in relation to the simulation software that will be used.

Although the practices are considered of great importance for the conceptual model construction, only GPs 2, 3, 4, and 10 are consolidated in the literature. This fact confirms that the CM stage is the least understood in the process of simulation and receives less attention than the ideal (Montevechi et al., 2010; Robinson, 2008; Wang & Brooks, 2007).

7. Conclusion

CM is an essential process for computer simulation, since it supports the modeller in the simulation project phases, avoiding rework. In this way, the objective of this work was to identify the state of the art of CM in computer simulation projects through an SLR, especially regarding their adherence to GPs. For this, we identified 13 GPs for CM in the literature, which aim at the development of effective conceptual models, i.e., models with suitable syntactic, semantic, and pragmatic quality. These GPs belong to five groups: language appropriateness, conceptual modelling process, syntactic quality, semantic quality, and pragmatic quality. Furthermore, we evaluated how the identified GPs relate to and support each other.

Finally, deficiencies were found concerning both the GPs and the quality of the studies' reports, suggesting future directions to overcome them. These deficiencies confirm that CM, although necessary for the simulation project, does not receive due attention from the modellers, as stated by (Robinson, 2008), (Wang & Brooks, 2007) and (Montevechi et al., 2010). By bringing together GPs (which are often not followed), this work contributes to increasing the chances of success of CM and its documentation, and consequently of simulation projects.

Acknowledgments

The authors thank the Coordenação de Aperfeiçoamento de Pessoal deNível Superior (CAPES), the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq), the Fundação de Amparo à Pesquisa do Estado de Minas Gerais (FAPEMIG) and Honeywell for supporting this research and the anonymous referees for suggestions that contributed to substantial improvements in the paper.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

This work was supported by the Conselho Nacional de Desenvolvimento Científico e Tecnológico; Coordenação de Aperfeiçoamento de Pessoal de Nível Superior; Fundação de Amparo à Pesquisa do Estado de Minas Gerais.

ORCID

Gustavo Teodoro Gabriel http://orcid.org/0000-0001-5884-1513
Afonso Teberga Campos http://orcid.org/0000-0001-7378-7711
Fabiano Leal http://orcid.org/0000-0001-9814-5352
José Arnaldo Barra Montevechi http://orcid.org/0000-0002-6443-5113

References

Abdulmalek, F. A., & Rajgopal, J. (2007). Analyzing the benefits of lean manufacturing and value stream mapping via simulation: A process sector case study. *International Journal of Production Economics*, *107*(1), 223–236. https://doi.org/10.1016/j.ijpe.2006.09.009

Agyapong-Kodua, K., Weston, R. H., & Ratchev, S. (2012). The integrated use of enterprise and system dynamics modelling techniques in support of business decisions. *Advances in Decision Sciences*, *2012*, 1–25. https://doi.org/10.1155/2012/804324

Agyapong-Kodua, K., & Weston, R. H. (2011). Systems approach to modelling cost and value dynamics in manufacturing enterprises. *International Journal of Production Research*, *49*(8), 2143–2167. https://doi.org/10.1080/00207540903436661

Alrabghi, A., & Tiwari, A. (2015). State of the art in simulation-based optimisation for maintenance systems. *Computers and Industrial Engineering*, *82*, 167–182. https://doi.org/10.1016/j.cie.2014.12.022

An, L., Jeng, -J.-J., Lee, Y. M., & Ren, C. (2007). Effective workforce lifecycle management via System Dynamics modeling and simulation. *Winter Simulation Conference. Proceedings of Winter Simulation Conference* (pp. 2187–2195). Washington.

Atieh, A. M., Kaylani, H., Almuhtady, A., & Al-Tamimi, O. (2016). A value stream mapping and simulation hybrid approach: Application to glass industry. *The International Journal of Advanced Manufacturing Technology*, *84*(5), 1573–1586. https://doi.org/10.1007/s00170-015-7805-8

Babashov, V., Aivas, I., Begen, M. A., Cao, J. Q., Rodrigues, G., D'Souza, D., Lock, M., & Zaric, G. S. (2017). Reducing patient waiting times for radiation therapy and improving the treatment planning process: A discrete-event simulation model (radiation treatment planning). *Clinical Oncology*, *29*(6), 385–391. https://doi.org/10.1016/j.clon.2017.01.039

Banks, J. (1998). *Handbook of simulation: Principles, methodology, advances, applications, and practice*. John Wiley & Sons, Inc.

Banks, J., Carson, J. S., Nelson, B. L., & Nicol, D. M. (2010). *Discrete-event system simulation* (5th ed.). Pearson Prentice Hall.

Baril, C., Gascon, V., Miller, J., & Côté, N. (2016). Use of a discrete-event simulation in a Kaizen event: A case study in healthcare. *European Journal of Operational Research*, *249*(1), 327–339. https://doi.org/http://dx.doi.10.1016/j.ejor.2015.08.036

Bem-Tovim, D., Filar, J., Hakendorf, P., Qin, S., Thompson, P., & Ward, D. (2016). Hospital event simulation model: Arrivals to discharge–design, development and application. *Simulation Modelling Practice and Theory*, *68*, 80–94. https://doi.org/10.1016/j.simpat.2016.07.004

Bevilacqua, M., Ciarapica, F. E., Mazzuto, G., & Paciarotti, C. (2015). The impact of business growth in the operation activities: A case study of aircraft ground handling operations. *Production Planning & Control: The Management of Operations*, *26*(7), 37–41. https://doi.org/10.1080/09537287.2014.939234

Biolchini, J. C. D. A., Mian, P. G., Natali, A. C. C., Conte, T. U., & Travassos, G. H. (2007). Scientific research ontology to support systematic review in software engineering. *Advanced Engineering Informatics*, *21*(2), 133–151. https://doi.org/10.1016/j.aei.2006.11.006

Bisogno, S., Calabrese, A., Gastaldi, M., & Levialdi, N. (2016). Combining modelling and simulation approaches How to measure performance.*Business Process Management Journal*, *22*(1), 56–74. https://doi.org/10.1108/BPMJ-02-2015-0021

Bublitz, A., Ringler, P., Genoese, M., & Fichtner, W. (2014). Agent-based simulation of the German and French wholesale electricity markets - Recent extensions of the powerACE model with exemplary applications. *ICAART. Proceedings of the 6th International Conference on Agents and Artificial Intelligence* (pp. 40–49). Angers, Loire Valley, France

Bureš, V. (2015). Comparative analysis of system dynamics software packages. *International Review on Modelling and Simulations*, *8*(2), 245–256. https://doi.org/10.15866/iremos.v8i2.5401

Caro, J. J. (2005). Pharmacoeconomic analyses using discrete event simulation. *Pharmacoeconomics*, *23*(4), 323–332. https://doi.org/10.2165/00019053-200523040-00003

Cheng, T., Feng, C., & Hsu, M. (2006). An integrated modeling mechanism for optimizing the simulation model of the construction operation. *Automation in Construction*, *15*(3), 327–340. https://doi.org/10.1016/j.autcon.2005.06.016

Choong, C. G., & McKay, A. (2014). Sustainability in the Malaysian palm oil industry. *Journal of Cleaner Production*, *85*, 258–264. https://doi.org/10.1016/j.jclepro.2013.12.009

Chwif, L., & Montevechi, J. A. B. (2015). Are visually appealing simulation models preferable? *Winter Simulation Conference* (pp. 159–170). Huntington Beach, CA, USA.

Clouth, J., Knoll, S., & Eichmann, F. (2010). Evaluating health care using system dynamics modelling – A case study in Schizophrenia. *Gesundh Ökon and Qualitats Management*, *15*, 302–310. http://doi.org/10.1055/s-0028-1109447

Cook, D. J., Greengold, N. L., Ellrodt, A. G., & Weingarten, S. R. (1997). The relation between systematic reviews and practice guidelines. [review] [58 refs]. *Annals of Internal Medicine*, *127*(3), 210–216. https://doi.org/10.7326/0003-4819-127-3-199708010-00006

Cournut, S., & Dedieu, B. (2004). A discrete events simulation of flock dynamics: A management application to three lambings in two years. *Animal Research*, *53*(5), 383–403. https://doi.org/10.1051/animres:2004025

Da Silva, C. E. S., Salgado, E. G., Mello, C. H. P., Da Oliveira, E. S., & Leal, F. (2014). Integration of computer simulation in design for manufacturing and assembly. *International Journal of Production Research*, *52*(10), 2851–2866. https://doi.org/10.1080/00207543.2013.853887

De Rangel, J. J. A., & Nunes, A. F. (2011). Use of IDEF-SIM to document simulation models. In: *Winter Simulation Conference* (pp. 2194–2205). Phoenix, AZ.

Dengiz, B., & Belgin, O. (2014). Simulation optimization of a multi-stage multi-product paint shop line with response surface methodology. *Simulation: Transactions Of The Society for Modeling and Simulation International*, *90*(3), 265–274. https://doi.org/10.1177/0037549713516508

Ding, X. J., & Sun, F. X. (2014). An overview of VV&A methods for conceptual model. *Applied Mechanics and Materials*, *444–445*,860–864. https://doi.org/10.4028/www.scientific.net/AMM.444-445.860

Djanatliev, A., & German, R. (2013). Prospective healthcare decision-making by combined system dynamics, discrete-event and agent-based simulation. *Winter Simulation Conference. Proceedings of Winter Simulation Conference* (pp. 270–281). Washington.

Dong, F., Liu, H., & Lu, B. (2012). Agent-based simulation model of single point inventory system. *Systems Engineering Procedia*, *4*(2), 298–304. https://doi.org/10.1016/j.sepro.2011.11.079

Dundović, Č., Bilić, M., & Dvornik, J. (2009). Contribution to the development of a simulation model for a seaport in specific operating conditions. *PROMET - Traffic&Transportation*, *21*(5), 331–340. https://doi.org/10.7307/ptt.v21i5.248

Edwards, P., Clarke, M., DiGuiseppi, C., Pratap, S., Roberts, I., & Wentz, R. (2002). Identification of randomized controlled trials in systematic reviews: Accuracy and reliability of screening records. *Statistics in Medicine*, *21*(11), 1635–1640. https://doi.org/10.1002/sim.1190

Ekyalimpa, R., AbouRizk, S., Farrar, J. 2012 Effective strategies for simulatinf one-of-a-kind construction projects. Winter Simulation Conference. Proceedings of Winter Simulation Conference (pp. 1–13). Berlin.

Elbanhawy, E. Y., Dalton, R., Shankar, V. N., & Warith, K. A. A. (2014). Hybrid-OD matrix based simulation approach to identify E-charging hotspots in transport network. *IEEE Transportation Electrification Conference and Expo (ITEC)* (pp. 1–6). Dearborn. https://doi.org/10.1109/ITEC.2014.686178.

Fayoumi, A., & Loucopoulos, P. (2016). Conceptual modeling for the design of intelligent and emergent information systems. *Expert Systems with Applications*, *59*, 174–194. https://doi.org/10.1016/j.eswa.2016.04.019

Flood, I. (2015). Computing in Civil Engineering. *2015 International Workshop on Computing in Civil Engineering* (pp. 692–699). Austin, Texas.

Francisco, R. P., Campos, D. P., Frazzon, E. M., & Machado, R. L. (2016). On the application of modelling and simulation to compare human- and automation-based order-picking systems. *IFAC-PapersOnLine*, *49*(12), 1062–1067. https://doi.org/10.1016/j.ifacol.2016.07.583

Fu-gui, D., Hui-mei, L., & Bing-de, L. (2012). Agent-based simulation model of single point inventory system. *Systems Engineering Procedia*, *4*, 298–304. https://doi.org/10.1016/j.sepro.2011.11.079

Furian, N., O'Sullivan, M., Walker, C., Vössner, S., & Neubache, D. (2015). A conceptual modeling framework for discrete event simulation using hierarchical control structures. *Simulation Modelling Practice and Theory*, *56*, 82–96. https://doi.org/10.1016/j.simpat.2015.04.004

Gagliardi, D., Niglia, F., & Battistella, C. (2014). Evaluation and design of innovation policies in the agro-food sector: An application of multilevel self-regulating agents. *Technological Forecasting and Social Change*, *85*, 40–57. https://doi.org/10.1016/j.techfore.2013.10.015

Gaion, S., Fanti, M. P., Mininel, S., Ukovich, W., & Vatta, F. (2009). Modelling and validation of alarm management workflow in healthcare integrating IHE-PCD profile and coloured petri nets. *IFAC Proceedings Volumes (IFAC-PapersOnline)*, *2*(PART 1), 169–174. https://doi.org/10.3182/20090610-3-IT-4004.00034

Garani, G., & Adam, G. K. (2008). Qualitative modelling at the design of concrete manufacturing machinery. *International Journal of Computers and Applications*, *30*(4), 325–330. https://doi.org/10.1080/1206212X.2008.11441912

Garousi, V., & Pfahl, D. (2016). When to automate software testing? A decision-support approach based on process simulation. *Journal of Software: Evolution and Process*, *28*(4), 272–285. https://doi.org/10.1002/smr.1758

Geller, A., & Alam, S. J. (2010). A socio-political and -cultural model of the war in Afghanistan. *International Studies Review*, *12*(1), 8–30. https://doi.org/10.1111/j.1468-2486.2009.00910.x

Harrell, C., Ghosh, B. K., & Bowden, R. (2012). *Simulation using promodel* (3th ed.). McGraw-Hill Education.

Heeg, B., Buskens, E., Knapp, M., Van Aalst, G., Dries, P. J. T., de Haan, L., & Van Hout, B. A. (2005). Modelling the treated course of schizophrenia: Development of a discrete event simulation model. *PharmacoEconomics*, *23*(Suppl 1), 17–33. https://doi.org/10.2165/00019053-200523001-00003

Hennemann, F. A., & Rabelo, R. J. (2006). A hybrid decision support system made up of Petri nets, simulation, and expert system. *Controle y Automação*, *17*(1), 10–23. https://doi.org/10.1590/S0103-17592006000100002

Herpel, T., & German, R. (2009). A simulation approach for the design of safety-relevant automotive multi-ECU systems. System of Systems Engineering, IEEE International Conference on System of Systems Engineering (SoSE) (pp. 1–8). Albuquerque.

Hou, S. (2013). Distribution center logistics optimization based on simulation. *Research Journal of Applied Sciences, Engineering and Technology*, *5*(21), 5107–5111. https://doi.org/10.19026/rjaset.5.4405

Huirong, W., & Xiaoning, Z. (2010). Analysis on key factors of container seamless transportation operating based on system dynamics. *2010 International Conference on Computer Application and System Modeling (ICCASM) . 2010 International Conference on Computer Application and System Modeling (ICCASM)* (pp. 379–382). Taiyuan, China.

Jagathy Raj, V. P., & Acharya, D. (2009). Evaluation of a proposed hot metal distribution system for an integrated steel plant using simulation. *International Journal of Operations and Quantitative Management*, *15*(4), 273–292.

Jahangirian, M., Eldabi, T., Naseer, A., Stergioulas, L. K., & Young, T. (2010). Simulation in manufacturing and business: A review. *European Journal of Operational Research*, *203*(1), 1–13. https://doi.org/10.1016/j.ejor.2009.06.004

Ju, F., Lee, H. K., Osarogiagbon, R. U., Yu, X., Faris, N., & Li, J. (2015). Computer Modeling of Lung Cancer Diagnosis-to-treatment Process. *Translational Lung Cancer Research*, *4*(4), 404–414. https://doi.org/10.3978/j.issn.2218-6751.2015.07.16.

Karagöz, N. A., & Demirörs, O. (2011). Conceptual modeling notations and techniques. In S. Robinson, R. Brooks, K. Kotiadis, & D.-J. Van der Zee (Eds.), *Conceptual modeling for discrete-event simulation* (pp. 179–209). Taylor & Francis Group.

Karnon, J. (2003). Alternative decision modelling techniques for the evaluation of health care technologies: Markov processes versus discrete event simulation. *Health Economics*, *12*(10), 837–848. https://doi.org/10.1002/hec.770

Kashimbiri, N., Chen, Y.-F., & Zhou, J.-X. (2005). Risk communications: Around the world. Assessment of effects of human development on the environment by using system dynamic modeling technique (SD): A case study of the Mkomazi watershed (Pangani basin) in Northeastern Tanzania. *Human and Ecological Risk Assessment*, *11*(2), 451–467. https://doi.org/10.1080/10807030590925641

Kitchenham, B., & Charters, S. (2007). Guidelines for performing systematic literature reviews in software engineering Version 2.3. *Engineering*, *45*(4ve), 1051.

Koivisto, M. (2017). Pitfalls in modeling and simulation. *Procedia Computer Science*, *119*, 8–15. https://doi.org/10.1016/j.procs.2017.11.154

Kress, R., Cemerlic, A., Kress, J., Varghese, J.2010 Inverse discrete event modeling for facility parameter estimation. Winter Simulation Conference. Proceedings of Winter Simulation Conference (pp. 861–868). Baltimore.

Krogstie, J., Lindland, O. I., & Sindre, G. (1995). Defining quality aspects for conceptual models. In E. D. Falkenberg, W. Hesse, & A. Olive (Eds.), *Information system concepts: Towards a consolidation of views* (pp. 216–231). Springer.

Landis, J. R., & Koch, G. G. (1977). The measurement of observer agreement for categorical data. *Biometrics*, *33*(1), 159. https://doi.org/10.2307/2529310

Li, S., Xu, W., & Liang, X. (2014). Dynamic model for paper mills facilities using template-based load modeling technique. *2014 IEEE/IAS. 50th Industrial & Commercial Power Systems Technical Conference* (pp. 1–11). http://ieeexplore.ieee.org/document/6839158/

Lin, C.-S., Yang, -C.-C., & Yeh, C.-H. (2015). Modeling and analysis of water resources system problems by using the causal feedback loop diagram of system dynamics. *WSEAS transactions on environment and development. WSEAS transactions on environment and development* (pp. 143–154).

Lindland, O. I., Sindre, G., & Solvberg, A. (1994). Quality in conceptual modeling. *IEEE Software*, *11*(2), 42–49. https://doi.org/10.1109/52.268955

Liraviasl, K. K., Elmaraghy, H., Hanafy, M., & Samy, S. N. (2015). A framework for modelling reconfigurable manufacturing systems using hybridized discrete-event and agent-based simulation. *IFAC-PapersOnLine*, *48*(3), 1490–1495. https://doi.org/10.1016/j.ifacol.2015.06.297

Liu, J., Yu, Y., Zhang, L., & Nie, C. (2011). An Overview of Conceptual Model for Simulation and Its Validation. *2011 International Conference on Advances in Engineering. 2011 International Conference on Advances in Engineering* (pp. 152–158). Nanjing.

Macal, C., & North, M. (2014). Introductory tutorial: Agent-Based modeling and simulation. *Winter Simulation Conference. Proceedings of Winter Simulation Conference*. Savannah.

Mahato, B. K., & Ogunlana, S. O. (2011). Conflict dynamics in a dam construction project: A case study. *Built Environment Project and Asset Management*, *1*(2), 176–194. https://doi.org/10.1108/20441241111180424

Martinez-Olvera, C. (2007). Reference model of the manufacturing execution activity in make-to-order environments. *International Journal of Production Research*, *47*(6), 1635–1659. https://doi.org/10.1080/00207540701636330

Martischnig, A., Voessner, S., & Stark, G. (2009). Agent based modeling and system dynamics in healthcare: Modeling two stage preventive medical checkup systems. *International Conference on Agents and Artificial Intelligence. Proceedings of the International Conference on Agents and Artificial Intelligence* (pp. 416–421).

Melão, N., & Pidd, M. (2006). Using component technology to develop a simulation library for business process modelling. *European Journal of Operational Research*, *172*(1), 163–178. https://doi.org/10.1016/j.ejor.2004.09.033

Merrill, J. A., Deegan, M., Wilson, R. V., Kaushal, R., & Fredericks, K. (2013). A system dynamics evaluation model: Implementation of health information exchange for public health reporting. *Journal of the American Medical Informatics Association*, *20*(E1), e131–e138. https://doi.org/10.1136/amiajnl-2012-001289

Mgbemena, C., & Bell, D. (2016). Data-Driven customer behaviour model generation for agent based exploration. *Proceedings of the 49th Annual Simulation Symposium*. Pasadena.

Montevechi, J., Silva Costa, R., Leal, F., & Pinho, A. F. & Jesus, J. T. (2009). Economic evaluation of the increase in production capacity of a high technology products manufacturing cell using discrete event simulation. *Winter Simulation Conference. Proceedings of Winter Simulation Conference* (pp. 2185–2196). Austin

Montevechi, J. A. B., Leal, F., de Pinho, A. F., Costa, R. F., de Oliveira, M. L. M., & Da Silva, A. L. F. (2010). Conceptual modeling in simulation projects by mean adapted IDEF:

An application in a Brazilian tech company. *Winter Simulation Conference. Winter Simulation Conference* (pp. 1624–1635). Baltimore.
Montevechi, J. A. B., Pinho, A. F., De, Leal, F., & Marins, F. A. S. (2007). Application of design of experiments on the simulation of a process in an automotive industry. *Winter Simulation Conference. Proceedings of Winter Simulation Conference*. Washington.
Moradi, S., Nasirzadeh, F., & Golkhoo, F. (2015). A hybrid SD–DES simulation approach to model construction projects. *Construction Innovation*, *15*(1), 66–83. https://doi.org/10.1108/CI-10-2013-0045
Negahban, A., & Yilmaz, L. (2014). Agent-based simulation applications in marketing research: An integrated review. *Journal of Simulation*, *8*(2), 129–142. https://doi.org/10.1057/jos.2013.21
Nicolae, O., Wagner, G., & Werner, J. (2010). Towards an executable semantics for activities using discrete event simulation. *Business Process Management Workshops. BPM 2009. International Conference on Business Process Management* (pp. 369–380). https://doi.org/10.1007/978-3-642-12186-9_35
Onggo, B. S. S. (2012). Bpmn pattern for agent-based simulation model representation. *Winter Simulation Conference. Proceedings of Winter Simulation Conference* (pp. 1–10). Berlin.
Orji, I. J., & Wei, S. (2015). An innovative integration of fuzzy-logic and systems dynamics in sustainable supplier selection: A case on manufacturing industry. *Computers and Industrial Engineering*, *88*, 1–12. https://doi.org/10.1016/j.cie.2015.06.019
Overmyer, S. P., Lavoie, B., & Rambow, O. (2001). Conceptual modeling through linguistic analysis using LIDA. *01 Proceedings of the 23rd International Conference on Software Engineering* (pp. 401–410). Toronto, Ontario, Canada.
Pace, D. K. (2000). Ideas about simulation conceptual model development. *Johns Hopkins APL Technical Digest*, *21*(3), 327–336.
Pace, D. K. (2002). The value of a quality simulation conceptual model. *Modeling and Simulation Magazine*, *1*(1), 9–10.
Pecek, B., & Kovacic, A. (2011). Business process management: Use of simulation in the public sector. *Economic Research-Ekonomska Istraživanja*, *24*(1), 95–106. https://doi.org/10.1080/1331677X.2011.11517447
Pehrsson, L., Ng, A. H. C., & Stockton, D. (2013). Industrial cost modelling and multi-objective optimisation for decision support in production systems development. *Computers & Industrial Engineering*, *66*(4), 1036–1048. https://doi.org/10.1016/j.cie.2013.08.011
Pereira, T. F., Montevechi, J. A. B., De Miranda, R. C., & Friend, J. D. (2015). Integrating soft systems methodology to aid simulation conceptual modeling. *International Transactions in Operational Research*, *22*(2), 265–285. https://doi.org/10.1111/itor.12133
Perez-Mujica, L., Terry, B., Duncan, R., Andrea, R., Max, F. C., & Jonathon, H. (2014). Developing a sustainability assessment tool for socio-environmental systems: A case study. *Int. Workshop on Simulation for Energy, Sustainable Development & Environment* (pp. 83–91). Athens, Greece.
Pisuchpen, R., & Chansangar, W. (2014). Modifying production line for productivity improvement: A case study of vision lens factory. *Songklanakarin Journal of Science and Technology*, *36*(3), 345–357.
Ramwadhdoebe, S., Buskens, E., Sakkers, R. J. B., & Stahl, J. E. (2009). A tutorial on discrete-event simulation for health policy design and decision making: Optimizing pediatric ultrasound screening for hip dysplasia as an illustration. *Health Policy (Amsterdam, Netherlands)*, *93*(2–3), 143–150. https://doi.org/10.1016/j.healthpol.2009.07.007
Robinson, S. (2008). Conceptual modelling for simulation Part I: Definition and requirements. *Journal of the Operational Research Society*, *59*(3), 278–290. https://doi.org/10.1057/palgrave.jors.2602368
Robinson, S. (2011). Conceptual modeling for simulation: definition and requirements. In S. Robinson, R. Brooks, K. Kotiadis, & D.-J. Van der Zee (Eds.), *Conceptual modeling for discrete-event simulation* (pp. 3–30). Taylor & Francis Group.
Robinson, S. (2013). Conceptual modeling for simulation. *Winter Simulation Conference. Proceedings of Winter Simulation Conference* (pp. 377–388). Washington.
Robinson, S. (2015). A tutorial on conceptual modeling for simulation. *Winter Simulation Conference* (pp. 1820–1834). Huntington Beach, CA, USA.
Robinson, S., Arbez, G., Birta, L. G., & Tolk, A. (2015). Conceptual modeling: Definition, purpose and benefits. *Winter Simulation Conference* (pp. 1558–4305). Huntington Beach, CA, USA.
Roca, R., Pace, D., Robinson, S., Tolk, A., & Yilmaz, L. (2015). Paradigms for conceptual modeling. *Proceedings of the 48th Annual Simulation Symposium* (pp. 202–209). Alexandria, Virginia.
Rossheim, R. J. (1963). Report on proposed american standard flowchart symbols for information processing. *Communications of the ACM*, *6*(10),599–604. https://doi.org/10.1145/367651.367657
Sahaf, Z., Garousi, V., Pfahl, D., Irving, R., & Amannejad, Y. (2014). When to automate software testing? Decision support based on system dynamics: An industrial case study. *ICSSP. ACM International Conference Proceeding Series* (pp. 149–158).
Sajjad, M., Singh, K., Paik, E., & Chang-Won, A. (2016). Social simulation: The need of data-driven agent-based modelling approach. *18th International Conference on Advanced Communication Technology (ICACT)* (pp. 818–821). Pyeongchang, South Korea.
Sandanayake, Y. G., Oduoza, C. F., & Proverbs, D. G. (2008). A systematic modelling and simulation approach for JIT performance optimisation. *Robotics and Computer-integrated Manufacturing*, *24*(6), 735–743. https://doi.org/10.1016/j.rcim.2008.03.013
Sargent, R. G. (2013). Verification and validation of simulation models. *Journal of Simulation*, *7*(1), 12–24. https://doi.org/10.1057/jos.2012.20
Schönemann, M., Herrmann, C., Greschke, P., & Thiede, S. (2015). Simulation of matrix-structured manufacturing systems. *Journal of Manufacturing Systems*, *37*(1), 104–112. https://doi.org/10.1016/j.jmsy.2015.09.002
Sharda, B., & Bury, S. J. (2011) Best practices for effective application of discrete event simulation in the process industries. *Winter Simulation Conference. Proceedings of Winter Simulation Conference* (pp. 2320–2329).
Shengqiang, L., Wilsun, X., & Xiaodong, L. (2014). Dynamic model for paper mills facilities using template-based load modeling technique. *2014 IEEE/IAS 50th Industrial & Commercial Power Systems Technical Conference* (pp. 1–11). Fort Worth.
Sobolev, B., Harel, D., Vasilakis, C., & Levy, A. (2008). Using the Statecharts paradigm for simulation of patient flow in surgical care. *Health Care Management Science*, *11*(1), 79–86. https://doi.org/10.1007/s10729-007-9026-7

Sousa, G. W. L., Carpinetti, L. C. R., Groesbeck, R. L., & Alken, E. V (2005). Conceptual design of performance measurement and management systems using a structured engineering approach. *International Journal of Productivity and Performance Management*, *54*(5/6), 385–399. https://doi.org/10.1108/17410400510604548

Squires, H., Chilcott, J., Akehurst, R., Burr, J., & Kelly, M. P. (2016). A framework for developing the structure of public health economic models. *Value in Health*, *19*(5), 588–601. https://doi.org/10.1016/j.jval.2016.02.011

Stainsby, H., Taboada, M., & Luque, E. (2009). Towards an agent-based simulation of hospital emergency departments. *2009 IEEE International Conference on Services Computing. 2009 IEEE International Conference on Services Computing* (536–539). http://ieeexplore.ieee.org/document/5283900/

Tako, A. A., & Kotiadis, K. (2015). PartiSim: A multi-methodology framework to support facilitated simulation modelling in healthcare. *European Journal of Operational Research*, *244*(2), 555–564. https://doi.org/10.1016/j.ejor.2015.01.046

Topping, C. J., & Odderskaer, P. (2004). Modeling the influence of temporal and spatial factors on the assessment of impacts of pesticides on skylarks. *Environmental Toxicology and chemistry/SETAC*, *23*(2), 509–520. https://doi.org/10.1897/02-524a

Tranfield, D., Denyer, D., & Smart, P. (2003). Towards a methodology for developing evidence-informed management knowledge by means of systematic review. *British Journal of Management*, *14*(3), 207–222. https://doi.org/10.1111/1467-8551.00375

Walton, B., Nawarathna, B., George, B. A., & Malano, H. M. (2009). Future water supply and demand assessment in peri-urban catchments using system dynamics approach. *18th World IMACS Congress and MODSIM09. International Congress on Modelling and Simulation: Interfacing Modelling and Simulation with Mathematical and Computational Sciences, Proceedings* (pp. 3872–3878).

Wang, B., Brême, S., & Moon, Y. B. (2015). Conceptual modelling and the project process in real simulation projects: A survey of simulation modellers. *Journal of Computers and Industrial Engineering*, *66*(10), 1669–1685. https://doi.org/10.1016/j.cie.2013.12.016

Wang, W., & Brooks, R. (2015). Conceptual modelling and the modelling process in simulation projects: A survey of simulation modellers. *Journal of the Operational Research Society*, *66* (10), 1669–1685. https://doi.org/10.1057/jors.2014.128

Wang, W., & Brooks, R. J. (2007). Empirical investigations of conceptual modeling and the modeling process. *Winter Simulation Conference. Proceedings of Winter Simulation Conference* (pp. 762–770). Washington.

Watson, P. F., & Petrie, A. (2010). Method agreement analysis: A review of correct methodology. *Theriogenology*, *73*(9), 1167–1179. https://doi.org/10.1016/j.theriogenology.2010.01.003

Williams, E. J., & Ülgen, O. M. (2012). Pitfalls in managing simulation project. *Winter Simulation Conference* (pp. 1219–1229). Berlin, Germany.

Yang, Z., & Liyi, Z. (2011). System dynamics modeling and simulation of information resources allocation of R&D cooperation in China. *International Journal of Digital Content Technology and Its Applications*, *5*(2), 21–33. https://doi.org/10.4156/jdcta.vol5.issue2.3

Yuriy, G., & Vayenas, N. (2008). Discrete-event simulation of mine equipment systems combined with a reliability assessment model based on genetic algorithms. *International Journal of Mining, Reclamation and Environment*, *22*(1), 70–83. https://doi.org/10.1080/17480930701589674

Zeigler, B. P., & Hammonds, P. E. (2007). *Modeling & simulation-based data engineering: Introducing Pragmatics into ontologies for net-centric information exchange* (1st ed.). Elsevier Academic Press.

Zhou, M., Zhang, Q., & Chen, Z. (2006). What can be done to automate conceptual simulation modeling? (pp. 809–814) *Winter Simulation Conference. Proceedings of Winter Simulation Conference*, Monterey.

Zou, Y., Yao, Y., Jiang, Z., & Tang, W. (2016). An overview of conceptual model for simulation. In L. Zhang, X. Song, Y. Wu (eds), *Theory, Methodology, Tools and Applications for Modeling and Simulation of Complex Systems. AsiaSim 2016, SCS AutumnSim 2016. Communications in Computer and Information Science* (pp. 96–100). https://doi.org/10.1007/978-981-10-2663-8_10

Zulkepli, J., & Mustafee, N. (2012). Hybrid simulation for modelling large systems: An Example of integrated care model. *Winter Simulation Conference. Proceedings of Winter Simulation Conference*. (pp. 1–12).Berlin.

Zupan, H., & Herakovic, N. (2015). Production line balancing with discrete event simulation: A case study. *IFAC-papersonline*, *48*(3), 2305–2311. http://dx.doi.org/10.1016/j.ifacol.2015.06.431

Appendix. This appendix is about data collected from the articles (Table 3)

Table 3. Database.

Article	Language	Simulation	Sector	Software	Year
(Abdulmalek & Rajgopal, 2007)	VSM	DES	Manufacturing	Arena	2007
(Agyapong-Kodua et al., 2012)	Causal loop/stock flow	SD	Manufacturing	Ithink	2011
(Agyapong-Kodua & Weston, 2011)	Causal loop/stock flow	SD	Other	Ithink	2012
(An et al., 2007)	Causal loop/stock flow	SD	Service	Not Mentioned	2007
(Atieh et al., 2016)	Flowchart	DES	Manufacturing	Arena	2016
(Babashov et al., 2017)	Flowchart	DES	Healthcare	Simul8	2017
(Baril et al., 2016)	Flow	DES	Healthcare	Arena	2016
(Bem-Tovim et al., 2016)	Flow	DES	Healthcare	Not Mentioned	2016
(Bevilacqua et al., 2015)	IDEF3	DES	Service	Witness	2015
(Bisogno et al., 2016)	BPMN 2.0	DES	Healthcare	Not Mentioned	2016
(Bublitz et al., 2014)	Flow	ABS	Service	Java	2014
(Bureš, 2015)	Causal loop/stock flow	SD	Other	Not Mentioned	2015
(Caro, 2005)	Flowchart	DES	Healthcare	Arena	2005
(Cheng et al., 2006)	CYCLONE	DES	Other	Cost	2005
(Choong & McKay, 2014)	Flow	HY	Manufacturing	NetLogo	2014
(Clouth et al., 2010)	Flow	SD	Healthcare	Vensim	2010
(Cournut & Dedieu, 2004)	Object oriented	DES	Other	TUTOVIN	2004
(Dengiz & Belgin, 2014)	Flow	DES	Manufacturing	Arena	2014
(Djanatliev & German, 2013)	Flow	HY	Healthcare	ProHTA	2013
(Dundović et al., 2009)	Flow	SD	Transport/Logistic	PowerSim	2009
(Ekyalimpa et al., 2012)	Flow	DES	Transport/Logistic	GPS	2012
(Elbanhawy et al., 2014)	Flow	HY	Transport/Logistic	Not Mentioned	2014
(Fayoumi & Loucopoulos, 2016)	Causal loop/stock flow	SD	Service	Not Mentioned	2016
(Francisco et al., 2016)	IDEF-SIM	DES	Manufacturing	FlexSim	2016
(Flood, 2015)	CYCLONE	DES	Manufacturing	Not Mentioned	2015
(Fu-gui et al., 2012)	Flowchart	ABS	Service	AnyLogic	2012
(Gaion et al., 2009)	Petri's net	DES	Healthcare	CPNTools	2009
(Gagliardi et al., 2014)	Flow	ABS	Other	JADEX	2014
(Garousi & Pfahl, 2016)	Causal loop/stock flow	SD	Service	Not Mentioned	2016
(Geller & Alam, 2010)	Flow	HY	Other	Repast	2010
(Heeg et al., 2005)	Flow	DES	Healthcare	Excel/@Rissk	2005
(Hennemann & Rabelo, 2006)	Petri's net	HY	Manufacturing	ProModel	2006
(Herpel & German, 2009)	State chart	DES	Service	AnyLogic	2009
(Hou, 2013)	Flow	DES	Transport/Logistic	FlexSim	2013
(Huirong & Xiaoning, 2010)	Causal loop/stock flow	SD	Transport/Logistic	VenSim	2010
(Jagathy Raj & Acharya, 2009)	Flowchart	DES	Transport/Logistic	SIGMA	2009
(Ju et al., 2015)	Flow	DES	Healthcare	Not Mentioned	2015
(Karnon, 2003)	Flow	DES	Healthcare	Not Mentioned	2003
(Kashimbiri et al., 2005)	Causal loop/stock flow	SD	Other	VenSim	2005
(Kress et al., 2010)	Flow	DES	Manufacturing	ExtendSim	2010
(Li et al., 2014)	Causal loop/stock flow	SD	Manufacturing	SPSS	2014
(Lin et al., 2015)	Causal loop/stock flow	SD	Other	Not Mentioned	2015
(Liraviasl et al., 2015)	IDEF0	HY	Manufacturing	AnyLogic	2015
(Mahato & Ogunlana, 2011)	Stock flow	SD	Transport/Logistic	Ithink	2011
(Martinez-Olvera, 2007)	IDEF0	DES	Manufacturing	Arena	2007
(Martischnig et al., 2009)	Causal loop	SD	Healthcare	Not Mentioned	2009
(Melão & Pidd, 2006)	Flowchart	DES	Service	BPSim++	2004
(Merrill et al., 2013)	Causal loop/stock flow	SD	Healthcare	Not Mentioned	2013
(Mgbemena & Bell, 2016)	Decision Tree	ABS	Service	TEA-SIM	2016
(Montevechi et al., 2007)	Map Flowchart	DES	Manufacturing	ProModel	2007
(Montevechi et al., 2009)	Flowchart	DES	Manufacturing	ProModel	2009
(Montevechi et al., 2010)	IDEF-SIM	DES	Manufacturing	ProModel	2010
(Moradi et al., 2015)	Causal loop/stock flow	HY	Other	AnyLogic	2015
(Nicolae et al., 2010)	BPMN	DES	Service	Java	2010
(Onggo, 2012)	BPMN	ABS	Other	Not Mentioned	2012
(Orji & Wei, 2015)	Causal loop/stock flow	SD	Manufacturing	Vensim	2015
(Pecek & Kovacic, 2011)	Swim lane Flowchart	DES	Healthcare	iGrafx	2011
(Pehrsson et al., 2013)	Flow	DES	Manufacturing	Not Mentioned	2013
(Pereira et al., 2015)	IDEF-SIM	DES	Manufacturing	ProModel	2015

(*Continued*)

Table 3. (Continued).

Article	Language	Simulation	Sector	Software	Year
(Perez-Mujica et al., 2014)	Causal loop	HY	Other	NetLogo	2013
(Pisuchpen & Chansangar, 2014)	Flowchart	DES	Manufacturing	Arena	2014
(Ramwadhdoebe et al., 2009)	Flow	DES	Healthcare	Arena	2009
(De Rangel & Nunes, 2011)	IDEF-SIM	DES	Manufacturing	Arena	2011
(Sahaf et al., 2014)	Causal loop/stock flow	SD	Service	Not Mentioned	2014
(Sajjad et al., 2016)	Flow	ABS	Other	AnyLogic	2016
(Sandanayake et al., 2008)	Flow	DES	Manufacturing	ProModel	2008
(Schönemann et al., 2015)	Flowchart	HY	Manufacturing	AnyLogic	2015
(Sharda & Bury, 2011)	Flow	DES	Manufacturing	ExtendSim	2011
(Shengqiang et al., 2014)	Flow	SD	Manufacturing	ETAP	2014
(Stainsby et al., 2009)	Flow	ABS	Healthcare	Not Mentioned	2009
(Sobolev et al., 2008)	Flowchart	DES	Healthcare	Not Mentioned	2008
(Sousa et al., 2005)	Causal loop/stock flow	SD	Service	Not Mentioned	2005
(Topping & Odderskaer, 2004)	Flow	ABS	Other	ALMASS	2004
(Walton et al., 2009)	Causal loop/stock flow	SD	Other	VenSim	2009
(Yang & Liyi, 2011)	Causal loop/stock flow	SD	Service	VenSim	2011
(Yuriy & Vayenas, 2008)	Flow	DES	Manufacturing	Simul8	2008
(Zulkepli & Mustafee, 2012)	Flow	HY	Healthcare	Simul8	2012
(Zupan & Herakovic, 2015)	Flow	DES	Manufacturing	Plant Simulation	2015