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Knowledge management in conducting simulation projects: a case study in consulting firms

A gestão do conhecimento na condução de projetos de simulação: um estudo de caso em empresas de consultoria

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Abstract: During a simulation project, modelers and customers acquire a greater knowledge of what is being simulated. However, much of this knowledge is lost due to the lack of ways to retain it and due to the lack of discussion about the types of knowledge present in the stages of a simulation project. In this context, this paper aims to present a case study to know how the projects are conducted and to identify the types of knowledge generated during their execution. The case study was performed in simulation consulting firms. Three companies specialized in the simulation were selected: a small one, a medium one, and a large one. It was identified that the four types of knowledge, established by the Nonaka and Takeuchi are present in each step of the simulation project. These results assist modelers in documenting and managing the knowledge and help them to avoid errors.

Keywords: Discrete event simulation; Knowledge management; Case study.

Resumo: *Durante a condução do projeto de simulação, analistas e clientes adquirem um maior conhecimento do que está sendo simulado, porém grande parte deste conhecimento é perdido, devido à ausência de formas de se retê-lo. Em boa parte, isto ocorre devido à falta de discussão com relação aos tipos de conhecimento presentes nas etapas de um projeto de simulação. Nesse contexto, este trabalho tem como objetivo apresentar um estudo de caso, a fim de conhecer como são conduzidos os projetos e identificar os tipos de conhecimento gerados durante sua realização, em empresas de consultoria em simulação. Para isto, foram escolhidas três empresas que trabalham com simulação, de pequeno, médio e grande porte. Como resultado, identificou-se que em cada etapa do projeto de simulação estão presentes os quatro tipos de conhecimento estabelecidos na espiral de Nonaka e Takeuchi. Estes resultados auxiliam os analistas na documentação e gestão do conhecimento e contribuem para evitar erros.*

Palavras-chave: *Simulação a eventos discretos; Gestão do conhecimento; Estudo de caso.*

1 Introduction

Discrete Event Simulation has been used increasingly employed to aid in decision making (Banks et al., 2005). For Law & McComas (2002), simulation is modeling manufacturing systems since the early 1960s.

Several research methods in the simulation are found in the literature, each one with its characteristics. Most of these methods are divided into three steps: conception, implementation, and analysis (Chwif & Medina, 2010; Montevechi et al., 2010).

In the course of a simulation research, analysts, modelers, managers, and customers of the simulation project, gain a better understanding of the system under study (Adamides & Karacapilidis, 2006; Robinson, 2008; Sargent, 2010).

However, this knowledge acquired during the simulation project remains hidden in the minds of the modelers and costumers, losing important details of the system itself, such as model programming, after the research is completed (Friend, 2012).

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According to Zhang et al. (2008) and Friend (2012), instead of wasting information at the end of each simulation project, which was obtained by the efforts of modelers, ways to retain knowledge should be developed, to guide future researches and highlight information to customers of the simulation.

As stated by Biz et al. (2013), information is one of the main strategies for the decision-making process of public, private and mixed organizations, being aligned with people management and information and communication technologies.

Considering the importance of this approach, a bibliometric study was conducted in the ISI - Web of Knowledge database, using the terms: Discrete Event Simulation and Knowledge Management. However, only 28 papers were found related to the research topics to be explored. Thus, it is noteworthy from this bibliometric study that there is a limited number of papers on these subjects, being considered an opportunity of study for potential simulation researchers.

In this context, this paper has as the objective to present a case study in order to know how simulation projects are conducted and identify the types of knowledge generated during the realization of a project in simulation consulting firms. To achieve this objective, research methods in the simulation and the knowledge spiral proposed by Nonaka & Takeuchi (1995) were studied and utilized.

The paper is organized into six sections. The first section contextualized the research problem. The second section presents the review literature on Discrete Event Simulation and Knowledge Management. The third section shows the methodological procedures used in this paper. The fourth section is represented the development of this method. The fifth section exhibits a presentation of the results and analyzes. Finally, the final section presents conclusions of this paper.

2 Review literature

2.1 Discrete event simulation

According to Bateman et al. (2013), simulation is an experimentation process with a detailed model of a real system to determine how a system will answer to changes in its structure, environmental or boundary conditions.

Simulation projects, as well as other types of projects, must be well structured and planned (Oliveira, 2010). Some methods of research in simulation, each with its characteristics, are present in the literature. Among them, the following stand out Mitroff et al. (1974), Maria (1997), Banks (1998), Law (2006), Chwif & Medina (2010) and Montevechi et al. (2010).

Conforming to Robinson (2008), a simulation project begins with the conceptual phase, in which researchers must know the process to be simulated, delimit the system, define the objectives of the research, scope and level of detail. Throughout the conception phase, a conceptual model is elaborated, which is an abstraction of the reality, performed using some process mapping tool.

Law (1991), Robinson (2008) and Pereira et al. (2012) found that conceptual modeling is probably the most difficult part of the simulation model development process, and that it should be well defined, so that, future mistakes are avoided.

With the elaboration of the conceptual model, model entry and exit variables are determined, data is collected for the simulation and adjusted to a better probability distribution, which is used in a computational model, in order to mimic the random behavior of the phenomenon simulated.

After these activities, the implementation phase begins. In this phase, the computational model is constructed, from the conceptual model (Sargent, 2010), using some simulation software. This computational model must be verified and validated. Verification consists of checking the model programming, analyzing the coherence of the logic used, and validation is to ensure that the computational model constructed represents the system being simulated (Sargent, 2010).

With the verification and validation of the computational model, simulation modelers can perform experiments and simulate the scenarios. From at this point, results of the simulation are generated, that after analysis of the modelers, are transformed into recommendations that will be made to the simulation's costumers. This phase is called analysis. If necessary, the model can be changed and the cycle restarted (Chwif & Medina, 2010).

2.2 Knowledge management

The term Knowledge Management (KM) was first used in the past decade by Davenport & Prusak (1998). These authors established the relationship between data, information, and knowledge.

The knowledge comes from information, the information being the consequence of ordering a set of data. This data set represents facts about a given event and compiles the portion of the stock of information that is recorded in the databases. On the other hand, information is the message that requires the existence of a sender and a receiver that perform the interpretation of a set of data (Davenport & Prusak, 1998).

According to Reginato & Gracioli (2012), information plays a fundamental role for organizations. The same authors believe that managing it effectively, using it as a strategic resource, contributes in an essential way to good planning.

Luban & Hîncu (2009) affirms that KM attempts to capture, store, maintain, and deliver the useful knowledge, meaningfully to any member of a company at any time. Anand & Singh (2011) define KM as the explicit and systematic management of knowledge and the processes associated with the creation, organization, dissemination, use, and exploitation of knowledge.

Although it is process oriented, with strategies determined by organizational culture, motivation, and policies, KM needs methods, technologies and tools for successful implementation (Luban & Hîncu, 2009). Orsi (2006) assumes that both existing knowledge and what must be acquired need to be systematically addressed, so that the company can take advantage of them in all its potential.

As reported by Ribeiro & Oliveira (2009) companies seek to encode and simplify this knowledge of individuals and groups to make it accessible to the organization as a whole. The value of knowledge coming from the organization must be added to the business, since the vision about an organization prepares it to, simply, process information tendentiously from external sources (Sampaio et al., 2012).

Nonaka & Takeuchi (1997) classify knowledge into two types: explicit knowledge and tacit knowledge. Tacit knowledge is considered the most important knowledge, it is personal knowledge, embedded in individual experience, difficult to decode into formal language, both oral and written. This knowledge is composed of intangible factors that guide the mind, such as paradigms, beliefs, perceptions, values, emotions, conclusions, subjective hunches, know-how, among others (Nonaka & Takeuchi, 1997).

On the other hand, explicit knowledge is one that involves accessible knowledge, which can be consciously articulated and is a characteristic of the person learning through explicit instruction, recitation of rules, attention to one's own movements, among others (Gupta et al., 2004).

According to Nonaka & Takeuchi (1997), the interaction between knowledge, tacit and explicit is the main dynamics of knowledge creation in the organization. This combination of one type of knowledge with another results in four types of knowledge: socialization, combination, externalization, and internalization, as can be seen in Figure 1.

The transference of tacit to tacit knowledge is called socialization. It is the process of sharing experiences and facilitates the creation of tacit knowledge (Nonaka, 1994). As reported by Friend (2012), socialization is the process of sharing experiences and creating tacit knowledge, such as mental models and technical skills. The transfer of tacit knowledge into explicit knowledge is called externalization. This process consists in the articulation of tacit knowledge into explicit, through actions that can be understood by others, whether this action is a dialogue or collective reflection (Nonaka & Toyama, 2003).

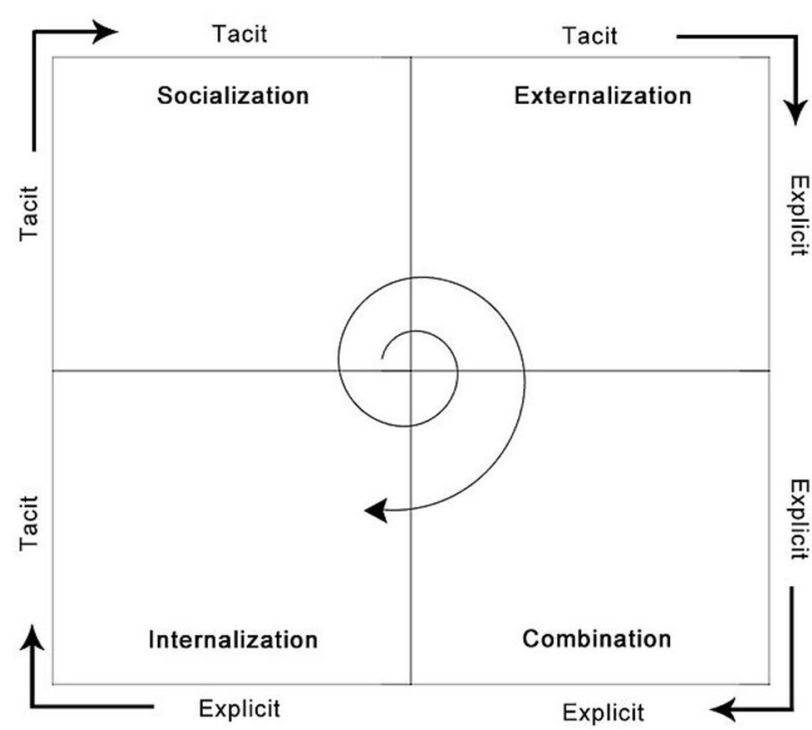

Figure 1. Types of knowledge. Source: Adapted from Nonaka & Takeuchi (1997).

The transfer of explicit to explicit knowledge is called a combination. It can be defined as explicit and collected knowledge inside and outside the organization and then combined, edited or processed in order to form a new explicit knowledge (Nonaka & Konno, 1998). The transfer of explicit to implicit knowledge is called internalization. When experiences of socialization, externalization and combination are internalized and become part of the tacit knowledge base of the individual, the process of creation and learning ends in the internalization phase (Nonaka & Takeuchi, 1995).

2.3 Study of the types of knowledge in the phases of the simulation project

According to the definitions proposed by Nonaka & Takeuchi (1995) following in this paper will be presented the types of knowledge utilized in each phase of the simulation project: conception, implementation, and analysis, based on research methods in simulation presented in the literature in order to aid modelers in the management and storage of the knowledge during the development of the projects.

In the first phase, conception, the objectives of the simulation will be defined. The simulation modelers perform several interviews with the specialists responsible by the system under study, knowing all the details of the process. This is the most demanding phase which requires more attention, so that the construction of the conceptual model faithfully represents the system that will be simulated.

The type of knowledge that fits in this phase is the socialization, in which there is an exchange of experience between people (Nonaka, 1991). The simulation modelers acquire the knowledge of the process under study from the specialists of the system through meetings, interviews, and conversations.

However, modelers also can acquire the knowledge of the process, from the documents already formalized, existing in the studied firm. This type of knowledge is called combination that as mentioned by Nonaka (1991), is the knowledge acquired through ways already formalized and registered. In this task, there are two types: socialization and combination.

In this phase, simulation modelers must build the conception model using a mapping technique. In other words, they must transform the knowledge that has acquired in a document, this knowledge is known by externalization that according to the definition of Nonaka (1991) is the knowledge that should be formally registered and available to other people.

The modelers must validate the conceptual model. This validation is done through meetings with the process specialists in which modelers present the built conceptual model and specialists approve and validate the model using this document.

If there is no approval, the system specialists highlight the critical points, and from there, propositions, corrections, and suggestions are made. Thus, another conceptual model must be constructed, faithfully representing the system. This should be re-introduced to the specialists for validation to take place. Validation is considered a very important step, since it is from this conceptual model that the whole system will be simulated.

In this sense, when there is generation of new knowledge from other documented and recorded knowledge, there is the combination. In this task, the modelers generate new knowledge, together with the specialists of the system, through the conceptual model, already constructed.

With the validation of the conceptual model, the modelers document the model so that the next phases of the simulation project can be performed. This documentation of knowledge, as stated by Nonaka (1991) is externalization, in which the registration and the formal provision of knowledge occurs. This document will be available to any member of the project team or customers, and customers will be able to acquire the transcribed knowledge.

Finally, the data collection and modeling of the input data is carried out, which will feed the computational model. Modelers visit the process being studied and collect data required for the model. If the company already has the information in some database or software and wishes to use this data, modelers may use this information already available with the permission of the company's management.

Here, modelers are getting the knowledge of other people or even of the process, collecting the necessary data. Thus characterizing as socialization, in which there is an exchange of experience between people (Nonaka & Takeuchi, 1995). Or, the modelers acquire the knowledge of documents already formalized and registered, characterizing the internalization. In this task, there are two types of knowledge, socialization and internalization.

In the implementation phase, modelers must build the computational model, from the validated conceptual model. The data collected and treated at the conception stage will be used to feed this model.

The knowledge, result of the phase, is generated from the explicit knowledge of the modelers, in the programming of the simulation software. Modelers gain the knowledge of manipulating simulation software, through training and courses. In the case of experienced modelers, this explicit knowledge joins tacit knowledge, in which they have acquired with their development experience in simulation projects.

This type of knowledge generated from formalized documents is the combination, and it is possible to generate new knowledge. There is also another type, socialization which consists of the knowledge that the modelers possesses with all their experience. In this context, modelers will build the computational model, from documented files, as the conceptual model, and from there, there is the generation of new knowledge, such as the combination. The modelers will be outsourcing all this knowledge, through the computational model, this type of knowledge is the externalization.

After the construction of the computational model, the verification of this model must be performed. Verification of a model is defined to ensure that the computer program and its implementation are correct. It can be done through the features of the simulation software. Modelers can check by analyzing the logic of the model and comparing it with the conceptual model so that errors can be corrected.

In this case, modelers generate new knowledge comparing two documents already registered and formalized, at this time changes can be made. Modelers also use the knowledge embedded in their experience and the knowledge of the other people involved in the study. This knowledge is socialization and combination.

Finally, the computational model must also be validated. The validation of the computational model is defined as the determination that the behavior of the simulated model holds enough precision to represent the real model in which it is simulating (Sargent, 2013). This validation can be performed by means of some techniques, such as statistical tests. At this moment, all the knowledge of modelers and other people in the process are used, thus there is socialization and combination.

In the implementation phase new knowledge is generated from already formalized documents, combination is the type of knowledge in which represents this task. But this knowledge is incorporated into the knowledge of other people, this type of knowledge is socialization.

The tangible result of this phase is the computational model which contains all knowledge that was necessary for its building, this type of knowledge is externalization. In the end, the modelers and people involved internalize the knowledge acquired by them, characterizing the internalization.

In the analysis phase, modelers will define the scenarios that will be simulated, the number of replication to be performed, which changes will be implemented in the current model, which variables will be changed, and which levels, among others changes that modelers want to analyze. From the constructed computational model, this information is defined with the needs of the customer of the simulation, at the moment the socialization is present.

At this moment, new knowledges are generated from the constructed computational model, describing, thus, the combination. However, if the develop team is composed of more than one person, there is also the exchange of experience among modelers, being characterized by socialization, and this involves the combination of knowledge between them.

Thus, the development of all the works planned by the modelers happens, being generated new knowledge, from the existing ones. This type of knowledge is the combination and also the exchange of experience between analysts, socialization.

After the development of the previous task, the simulation presents to modelers with numerous data and results. Thus, the analysts perform a statistical analysis of the data, considering important aspects that were defined at the beginning of the simulation to be studied. Modelers formalize and record these analyzes, so that other people, especially the customers of the simulation, can acquire this knowledge, this form of knowledge is the externalization. But for these analyzes to be performed, modelers also study the data in the reports, this knowledge is the combination, where new knowledge is generated, from existing documents.

Finally, the modelers make conclusions and recommendations to the customers from the results and studies that were possible with the use of the simulation. Those involved in the system in question internalize the learning developed throughout the project, this type of knowledge is internalization.

At the moment, there is also an exchange of knowledge and experience, because modelers transfer the knowledge acquired about the project to the customers, who are interested in the simulation, this type of knowledge is socialization.

The results of the simulation are documents and recorded by analysts, this knowledge is improved so that anyone can understand it, and it is taken directly to the customers. This type is called externalization. Based on the suggestions and recommendations made by modelers, customers make decisions and decide what changes will be implemented in the real system, and they internalize the knowledge.

Figure 2 shows the knowledge spiral proposed by Nonaka & Takeuchi (1995) applied in the modeling and simulation method, which was developed by the authors. In the first phase of the simulation project (conception), there are four types of knowledge. In the second phase (implementation), the four types of knowledge are also present. Finally, in the last stage of the simulation project, as in the previous ones, the four types of knowledge are also found.

3 Methodology

The research method used in this study was the case study. According to Yin (2010), the case study is an empirical study that investigates a certain phenomenon, usually contemporary, within a real context, when the boundaries between the phenomenon and the context in which it is inserted are not clearly defined. The case study followed the following steps:

- Literature revision;
- Description of the case;
- Analysis of results and conclusions.

The case study is a kind of history of the phenomenon, extracted from multiple sources of evidence, in which any fact relevant to the current of events that describe the phenomenon is a given potential for the method, since the context is important (Miguel, 2010).

Yin (2010) proposes a procedure for conducting the case study, which was used in this work (Figure 3).

4 Development of the methodology

As shown in Figure 3, the procedure for conducting the case study proposed by Yin (2010) will be followed for the development of this paper.

4.1 Develop the theory

The first step proposed in the Yin (2010) procedure is the development of the theory. This first step was explained in topic 2 of this paper.

4.2 Select cases

The second activity proposed in the Yin procedure (2010) is the selection of cases. According to the survey conducted by D'Audenhove & Fugihara (2009), between 1999 and 2008, approximately

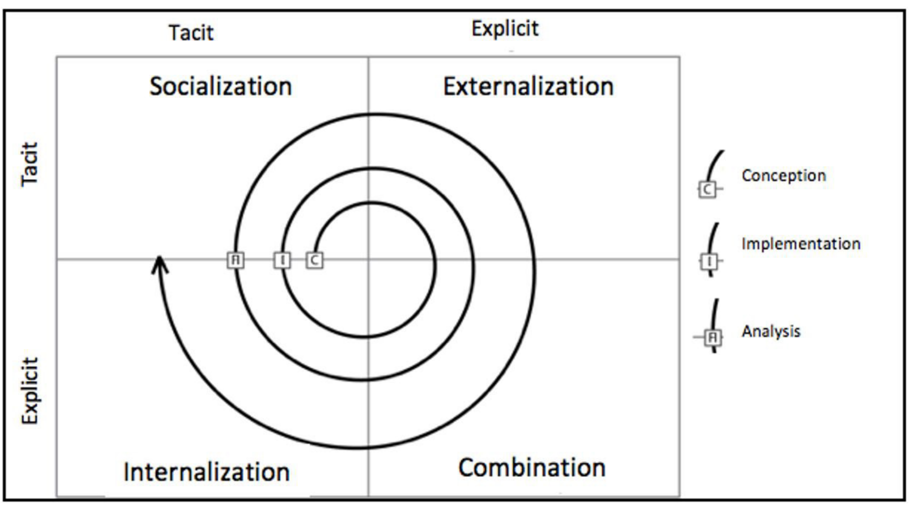

Figure 2. Knowledge spiral applied in the simulation method. Source: Adapted from Nonaka & Takeuchi (1997).

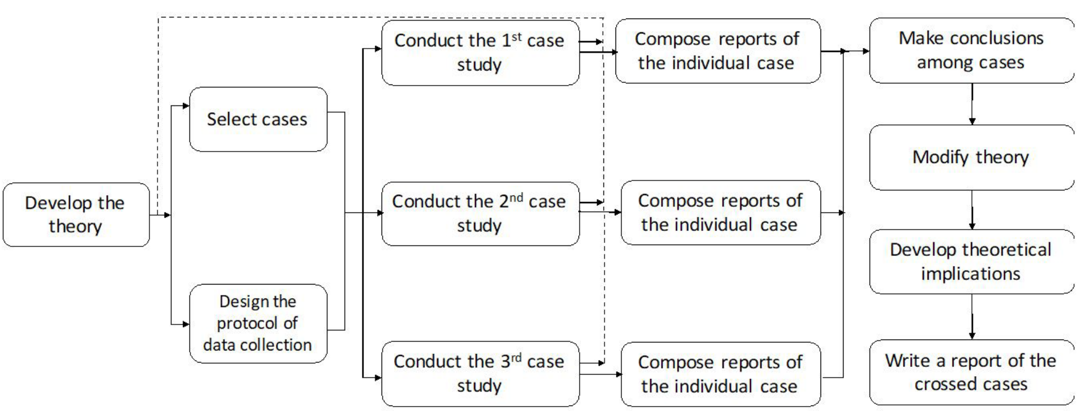

Figure 3. Conducting the case study. Source: Yin (2010).

40 Brazilian companies were identified that apply and use discrete event simulation.

Based on this research by D'Audenhove & Fugihara (2009), three companies were selected for the development of the present case study. It is intended to study these three companies, illustrate the conduct of the projects, since the selected companies are of different sizes, being a small company, a medium company and a large company. The names were omitted for confidentiality, so they will be called, respectively, company A, B and C.

The study focused on analyzing only consulting firms, after all these companies perform numerous simulation projects during the year and to gain a better understanding of the conduct of these projects. The aim is to collect valuable information from simulation customers and modelers in order to contribute to the reduction of errors and to guide the development of a project.

4.3 Designing the data collection protocol

The third activity of the Yin (2010) procedure is the data collection protocol project. The way for the researchers in this study obtained the data necessary for the research was an interview. According to Marconi & Lakatos (2006), an interview is a meeting between two people or more, in order to obtain information about a particular item, through a conversation of a professional nature. There are different types of interviews, which vary according to the researcher's purpose:

- Structured: the one in which the interviewer follows an established script;
- Unstructured: the interviewer is free to develop each situation in any direction that seems appropriate;
- Panel: consists of the repetition of questions, from time to time, to the same people, in order to study the evolution of opinions in short times.

For this paper, a structured interview was utilized, in which the researchers developed a questionnaire previously to be followed. This questionnaire is presented in Chart 1.

4.4 Conduct of case studies

The fourth activity proposed by Yin (2010) is the conduction of the case study. This way, it will be described how the study was conducted.

The first company of this study, called company A is a large Brazilian company, which has an internal group of modelers, focused on the development of simulation projects. For the research to be carried out, the researchers of this paper got in contacted with the responsible for the sector of the development of simulation projects in company A, thus a specific modeler was selected to answer the research questions.

Company B is a medium Brazilian simulation consulting company and other areas. It is a consolidated company in the market, which has numerous cases in simulation. In the same way as company A, a contact was made with the person in charge of company B, selecting a simulation modeler to answer these research questions.

Finally, Company C is a small Brazilian simulation consulting company and also in other areas, which has been consolidated in the market as well. Thus, as company A and B, a contact was made with the person in charge of company C, however, the owner of the company himself was able to answer the questions of the paper.

In all three companies, the way of developing simulation projects is similar. The Project Manager scales, on average, 3 modelers for the development of each project. These modelers go to the company that hired the service and collect the necessary data.

In order to obtain the necessary information for the study, the used questionnaire was presented in Chart 1. In companies A and C, this questionnaire

Chart 1. Questionnaire on knowledge management in simulation projects.

	Questionnaire on knowledge management in simulation projects
1	How are simulation projects conducted within the consulting firm?
2	What kind of knowledge is generated in each of the phases of the simulation?
3	Is any research method in the literature used during the development of the simulation projects?
4	Within the procedure adopted by the modelers, which moment of the simulation project is more difficult and complex to be executed?
5	Is there customer interaction in the conduct of the simulation project? At what times?
6	What are the main files generated while driving the projects?
7	How is stored the knowledge generated during the projects?
8	Is important the knowledge generated during project development to the simulation modelers? And for customers?
9	Is the knowledge generated in a simulation project used in other projects?

was sent by e-mail, in the form of an electronic questionnaire, in which modelers were able to respond it. In company B, a meeting was scheduled with the modeler, and one of the researchers with the questionnaire, in hand, conducted the interview. The researcher was authorized to record the meeting for further consultation. Thus, it was possible to obtain the necessary information for this study.

5 Results and analysis

The following activities of the procedure proposed by Yin (2010), consists of writing the report, draw conclusions, modify the theory, develop the theoretical implications and describe a report of the cases. To conclude these activities, the results obtained from the interviews and the analyzes will be presented, following the questionnaire used to collect data.

The first question asked how simulation projects are conducted within the consulting firms. The answer given by the respondent of company A was as follows:

> *First, there is an understanding of the problem about what will be simulated in the company that requested the service. Then, this understanding is transcribed into a conceptual model. With this conceptual model completed, one can then collect the data of each process of the system, and after this collection these data are processed. After data collection and analysis, the computational model is built, and then validated. Finally, the model is running and the results of the simulation are generated, these results are analyzed and interpreted. At the end, conclusions and recommendations are transferred to the customer of the project.*

The answer given by modeler from company B was as follows:

> *The development of simulation projects depends on the demand that a company has, when the customer requests a project for a simulation project in his company, the Project Manager of our company chooses the modelers who have a greater knowledge in that object of study and scale them to develop this project. Generally, this simulation team is composed of three modelers. The project has a minimum duration of 6 months and a maximum of one year, but the time is established during the negotiation with the customer, also depending on the level of complexity of the project to be simulated.*

Still as reported by the interviewee:

> *After negotiating our company with the customer, the scaled team has free access to the information of the object of the study. However, some customers do not allow photos or videos to be taken of the process being studied, but the modeler can consult all company's information available in their database and also from the employees. The modeler receives a company name tag to move around in and out of the system under study, tries to collect as much information as possible, through conversations with employees and managers, with indirect observations and collecting the necessary data.*

The interviewee continues with the description:

> *With this information in hands, the modeler in the consulting firm itself builds the conceptual model, and then the computational model with a specific simulator. Only if necessary he does return to the company and to the process being simulated.*

The interviewee pointed out that this was done many times, since some information or data was always lacking for the construction of the computational model.

Finally, the interviewee concludes:

> *After the whole procedure of data collection and construction of the computational model, the modeler finishes the simulation project, running the computational model, analyzing the data and transforming them into conclusions and recommendations. The final delivery meeting is scheduled and analysts deliver the completed project to the customers.*

It should be noted that in the consulting firm itself, there were several meetings with the manager to present the progress of the project. In these fortnightly meetings, the modeler responsible for a given project presented the results and was debated points to be improved, not yet involving the customer.

In company C, the contact was carried out via email, as previously mentioned. The interviewee briefly reported on how the projects are conducted. It presents that initially a diagnosis of the system under study is realized. Next, the system mapping is constructed, that is, the process status is described and what will be simulated. Subsequently, the data required to feed the computational model is collected and, after this collection, the data are processed. With this, the construction of the computational model is started, using a specific simulator. The model is running and the first results of the simulation are emitted. These results are analyzed, different scenarios are constructed and different interpretations are made. Finally, by concluding the project, results and recommendations are presented to the customer.

With the answers obtained in this first question, then it was possible to answer the next question: "What kind of knowledge is generated during the simulation project?".

To answer this question were gathered the answers obtained to present in an organized way the generation of knowledge while conducting the simulation projects. It should be remembered that there are four knowledge established by Nonaka & Takeuchi (1995): socialization, externalization, combination, and internalization.

At first, modelers were allowed to frequent the company and have access to any kind of information, both from people and from files already documented. This type of knowledge is socialization, which allows to obtain new knowledge from the others, and internalization, in which the modeler acquires the knowledge of documented. At the moment, the objectives were also defined that the simulation would respond, that way you have the combination as the type of knowledge.

After obtaining the data for the simulation, the modeler documented this information so that the customers or the Project Manager could acquire this knowledge. This knowledge is externalization, which consists in articulating knowledge into something tangible.

Then, in the implementation phase, the modeler builds the computational model, based on the documented information, charactering the externalization. But, the modeler can also build a new computational model in case other experienced modelers think about the model, or even from their own implicit knowledge. This mix of knowledge is named combination. It is recalled that at this point, the modeler can return to the system to collect more information, if necessary, from both documents and people, in that way, socialization and internalization are again recognized. At the end of the construction of the computational model, the modelers internalize all the knowledge that was generated in this phase.

Finally, the modelers analyze the simulation data and from there, generate the conclusions of the simulation. This type of knowledge that generates new knowledge from registered documents is the combination. The modelers also present these results to the customers of the simulation, having, at that moment, a transfer of knowledge from modeler to customers, with the exchange of experiences, called socialization. Also, these results are documented, charactering the externalization. At the end, all the knowledge generated from this phase is internalized by members.

From this summary description made through the answers obtained, it was possible to identify the types of knowledge generated in each of the activities of the simulation project. It was found that in the three phases of a simulation project: conception, implementation, and analysis, the four types of knowledge are present: socialization, externalization, combination, and internalization, as established by Nonaka & Takeuchi (1995). In this context, this finding corroborates the proposition in Figure 3, where it demonstrates the knowledge spiral applied in the phases of the simulation project and, it is said that, really, what is described in the spiral is what happens inside the simulation projects of the consulting firms studied.

The third question asked to the respondents about the simulation research method. If in the company generally use some method or if they are aware that these methods exist. The respondents of company A and C, answered that they do not know any method of research in simulation. The way the projects are conducted is done according to the procedure of each modeler and based on their own personal knowledge that these professionals have and choose to develop the projects.

The respondent from company B said that some modelers were familiar with some simulation research methods because they did courses related to the area. However, other modelers did not know about them. These modelers who do not know them follow their own method, which they themselves develop during the project. Those who know some method follow it correctly.

The fourth question addressed: "Within the procedure adopted by the modelers, which moment of the simulation project is more difficult and complex to be executed?". The answer given by the respondent of company A was the modeling of the input data and the validation of the computational model. For the modeler of company B, the answer was as follows:

> *The most complex part of developing a simulation project is the initial part, in which the problem is conceptualized, because it is a consulting company, modelers do not have knowledge of what will be simulated, until they truly understand the process and all the variables that are present, it is the most complex part and consuming more time.*

For the respondent of company C, it was the construction of the conceptual model.

According to the answers of the fourth question, it is noted that the phase cited by the modelers of companies' B and C, is the initial phase of the project, conception. As discussed earlier in this paper, authors such as Law (1991), Robinson (2008), and Pereira et al. (2012) argue that the initial phase is more complex and demands more time. From the answers obtained here, this affirmation is confirmed.

The fifth question asked if there is customer interaction in the conduct of the simulation project, if there was this interaction, it would occur in which moments. For the respondent of company A, there is customer interaction at the beginning of the scope definition, during its validation and also in the validation of the computational model.

The interviewee of company B pointed out that during the development of the project there was the interaction of the customer, however, they were just few participations. The first one usually occurred after the conceptual model was elaborated, where modelers scheduled meetings with customers to show the results of the project at that moment. The second occurred after the construction of the computational model. The modeler pointed out that in this meeting customers interact more than in the first one because they do not have the necessary knowledge to make great interactions in the conceptual model. In the computational model, due to the simulation and the visual resources, the customers really understand what is happening in the project. The last contact with the customer happens at the conclusion of the project, in which the modelers deliver the final results.

According to the modeler of company C, there was customer interaction in the project, only during the presentation of the final results. As illustrated by the modeler, customers asked for new analysis and new changes, given the power of simulation to answer questions, such as: “What would happen if ...?”. Faced with this situation, the modeler pointed out that there was rework, coming from an ill-defined scope.

The sixth question asked about the main files generated during the simulation projects. Modelers pointed out that all the knowledge acquired by them was documented. As an example is the conceptual model in image format, Excel® worksheets, in which there are data about the processes involved in the system, such as versions of the computer model in specific format of the simulator, videos (when available by companies). It is important to emphasize as approached by the modeler of company B, that if he has access to videos of the studied process, it have facilitated the development of the work, since the time of travel to the company and influences during a collection of times, have impacted on project’s performance.

Question seven asked how this knowledge was stored. Based on the modelers’ responses, they pointed out that all the files on the simulation project were stored on company computers and had free access to manage them. When questioned if they could transfer this data to their personal computer, only the modeler of company B said that he had this access, other modelers are not allowed to work outside the company for security reasons.

The respondents from companies A, B, and C said that all files that the modeler knew about were stored on the consulting firm’s computer and had free access to how to store data.

The eighth question was: “Is important the knowledge generated during project development to the simulation modelers? What about customers?”. For the respondent of company A, knowledge can greatly help those involved in the study, such as to know the system itself. But he highlighted the importance of storing this knowledge properly, so that other people can have access to this information and know how to use it in the right way.

According to the respondent of company B, this knowledge helps during the conduction of the project, to understand the process, to build the conceptual and computational model, to carry out the experiments, in short in all activities for the modeler. For the customer, it assists in presenting the delivery of the final results, because as pointed out by the respondent, the customers want a fast result of the simulation, not being worried about its execution.

However, for the respondent of company C, the knowledge can help in the detection of errors and in the improvement of the process as a whole.

Is the knowledge generated in a simulation project used in other projects? This was the last question addressed in the study questionnaire. According to the respondent of company A, the knowledge is used in other projects, such as: the method used, the basis for the construction of the conceptual model, the routines of the computational model, the different types of analysis and the sources of the input data. “This knowledge serves as support and guide for other projects,” were words provided by the modeler of company A.

According to the respondents of company B and C, the knowledge gained from running a simulation project is embedded in their experience and is certainly used in other projects, learning from mistakes and rework. They highlighted that the storage of this knowledge that was acquired throughout the project is fundamental to guide future projects.

From all the above discussion, addressing issues present in the questionnaire, from Chart 1, a summary table (Chart 2) was elaborated, containing an overview of the results obtained through the interviews in companies A, B, and C.

The study and analyzes presented here intend to contribute with potential modelers and researchers in simulation in the conduct of projects, in order to avoid possible errors and future rework. It was also tried to enrich the analysis of the types of knowledge present in each project activity, since it is a little explored topic in the literature, but, above all, it can contribute to good simulation projects being developed.

Chart 2. Summary: overview of the results obtained in companies A, B, and C.

Questions	Company A	Company B	Company C
1. How are simulation projects conducted within the consulting firm?	- Conception of the problem - Construction of the conceptual model - Data collection - Treatment of these data - Construction of the computational model - Validation of the computational model - Execution of the model - Analysis of results - Conclusions and recommendations to the customer.	- Conception of the problem - Data collection - Construction of the computational model - Execution of the model - Analysis of results - Conclusions and recommendations to the customer.	- Conception of the problem - Construction of the conceptual model - definition of simulation objectives - Data collection - Data processing - Construction of the computational model - Execution of the model - Analysis of results - Conclusions and recommendations to the customer.
2. What kind of knowledge is generated in each of the phases of the simulation?	- Conception: Socialization, internalization, externalization, and combination - Implementation: Socialization, internalization, externalization, and combination - Analysis: Socialization, internalization, externalization, and combination		
3. Is any research method in the literature used during the development of the simulation projects?	Do not know methods of research in simulation and use own procedure.	Some analysts know and use it. Others use their own procedure.	Do not know methods of research in simulation and use own procedure.
4. Within the procedure adopted by the modelers, which moment of the simulation project is more difficult and complex to be executed?	- Modeling of the input data; - Validation of the computational model.	- Conception of the problem.	- Construction of the conceptual model.
5. Is there customer interaction in the conduct of the simulation project? At what times?	Yes, during the conception of the problem, validation of the conceptual model, and validation of the computational model.	Yes, during the validation of the conceptual model, validation of the computational model, and delivery of the results.	Yes, only in the presentation of the final results.
6. What are the main files generated while driving the projects?	Conceptual model in image format, Excel® spreadsheets, which contained the data about the processes involved in the system, the computer model versions in a specific format of the simulator, the project reports in document format and videos (when available by the companies)		
7. How is stored the knowledge generated during the projects?	It has free form of storage but no access to data outside the company.	It has free form of storage and has access to data outside the company.	It has free form of storage but no access to data outside the company.
8. Is important the knowledge generated during project development to the simulation modelers? And for customers?	Yes, it helps those involved to get to know the system itself. But it should store them properly.	Yes, it assists during the conduction of the project, to understand the process, to build the conceptual and computational model, to carry out the experiments, in short, in all activities for the analyst. However, for the customer, it assists in the presentation of the delivery of the final results.	Yes, it helps in detecting errors and improving the process as a whole.
9. Is the knowledge generated in a simulation project used in other projects?	Yes, this knowledge certainly helps and guides other projects.	Yes, the knowledge gained from running a simulation project is built into your experience and is certainly used in other projects, learning from mistakes and rework.	Yes, the knowledge gained from running a simulation project is built into your experience and is certainly used in other projects, learning from mistakes and rework.

6 Conclusion

Chwif & Medina (2010) and Montevechi et al. (2010) propose methods that divide the simulation into three phases: conception, implementation, and analysis. In each of these phases, a greater understanding of what is being simulated is generated. However, this knowledge remains retained in the minds of modelers, and even simulation customers.

In this sense, in order to identify what kind of knowledge is generated in each activity of a simulation project and present how they are conducting these projects under the perspective of consulting companies, a case study was carried out, using the knowledge and research methods in the literature.

In order to comply with the objective established in this paper, the researchers selected three simulation consulting companies: a large company, a medium company, and a small simulation consulting company, this selection was motivated to illustrate the conduction of the projects in different types of companies.

A contact was made with the managers of these companies, presenting the study proposal and how the research would be. These managers have demonstrated interest and selected appropriate modelers to transmit the information needed for the study. With this, the interview with these modelers could be done, which was guided by a previously elaborated questionnaire to collect data.

The data obtained showed how the simulation projects are conducted in consulting companies and allowed to identify the types of knowledge generated throughout the projects, fulfilling the objectives established at the beginning of the research. Some results of the study could be highlighted, such as: for the execution of the simulation projects are scaled some specific modelers, and some modelers do not know the simulation research methods present in the literature, and some know these methods, but due to their background, many of the modelers do not follow a guide, but rather a structure developed by themselves.

It was also found that there is customer interaction in the development of the project, however, they are not concerned with the development of activities, but with the final result. In the consulting companies, a follow-up of the projects is carried out, with debates and proposals for improvements.

Generally, the projects have a minimum duration of 6 months and a maximum of 1 year, depending on the negotiation made with the customer and also the complexity.

Complying with one of the objectives established at the beginning of the paper, the types of knowledge generated in each of the activities of the simulation project were identified. It was found that in the three phases of a simulation project: conception, implementation, and analysis, the four types of knowledge are present, socialization, externalization, combination, and internalization, established by Nonaka & Takeuchi (1995). Within this context, this finding corroborated with the proposal of the knowledge spiral applied in the phases of the simulation project and, it is said that, really, what is described in the spiral is what happens within the simulation projects of the consulting companies studied.

Complying with the other objective proposed in the article, it was possible to know how the simulation projects are conducted, under the vision of consulting companies, of different levels. This study aimed to collaborate with modelers and researchers in simulation, in the management and documentation of the knowledge generated during the development of the phases, since it approached the types of knowledge involved. Also to avoid possible mistakes are made, since the adequate storage of knowledge can help in this task. And more significant of all, to avoid that all the knowledge acquired by the involved ones is lost in the time, being that these can be of great importance of the development of projects of simulation.

Finally, the accomplishment of this paper expands the discussion about the knowledge management as support to the process of decision-making through simulation projects. As presented throughout the paper, this field is often neglected, leading to problems while conducting a simulation project. Thus, with the discussion raised here, it is hoped to facilitate the decision-making process and the management of productive systems by the managers, integrating knowledge management and the simulation.

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