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METHODOLOGY FOR THE MANAGEMENT OF DISCRETE EVENT SIMULATION PROJECTS BASED ON PMBOK®: ACTION RESEARCH IN A HIGH-TECH COMPANY

Tábata Fernandes Pereira
Luiz Felipe Pugliese

Campus in Itabira
Federal University of Itajubá
R. Irmã Ivone Drumond, 200
Itabira, MG, 35903-087, BRAZIL

José Arnaldo Barra Montevechi
Mona Liza Moura de Oliveira

Industrial Engineering and Management Institute
Federal University of Itajubá
Av. BPS, 1303, Pinheirinho
Itajubá, MG, 37500-000, BRAZIL

Stewart Robinson

School of Business and Economics
Loughborough University
Loughborough
Leicestershire, LE11 3TU, UK

Amarnath Banerjee

Department of Industrial and Systems Engineering
Texas A&M University
3131 TAMU, College Station
Texas, TX 77843, USA

ABSTRACT

Discrete Event Simulation (DES) is a powerful tool for decision making. It has been widely used in different application fields. There are many works investigating the simulation modeling process, but little is found in the literature that considers how to manage a DES project. In this respect, this paper has the objective of proposing a specific methodology for the management of DES projects based on PMBOK®. This was considered to be the methodology that most fits with the requirements of DES. In order to test the approach, PMBOK® was applied in a real simulation project. The methodology was then evaluated by the simulation analysts who provided their feedback on the study.

1 INTRODUCTION

Discrete Event Simulation (DES) is considered to be a powerful tool to aid decision making, used to study and analyze, especially, complex systems, through computational models (Banks et al. 2009; Andersen 2016; Pereira et al. 2015). Although DES is a widely used modelling approach, little is known about modelling processes and methodologies adopted by practitioners (Tako 2014).

In this respect, Sturrock (2014) states that developing a simulation project is much more than just building a computational model, it requires skills that go beyond knowing just about a particular simulation tool. Balci (1989) argues that in considering the execution of DES, it is no challenge to develop a computer model that accepts a set of inputs and produces a set of outputs, but the challenge is to do it right.

This paper is based on this line of reasoning, starting from the principle that DES is a multidisciplinary science, thus integrating two lines of research that until the present moment have largely been studied separately: DES and Project Management. Through the investigations and systematic review of the literature, it has been verified that the studies in the area of DES are largely directed to the improvement of the process of developing the simulation model, or to improve the elaboration of the conceptual models, or to establish the use of tools that contribute to the data collection and analysis phase of the model. However, when considering the management of simulation projects, a gap has been identified in the literature. A bibliometric study was carried out in this field and only a few articles were found that allude to the use of project management in the simulation. These were not directly addressing the problems associated with project management and DES, and this paper intends to explore this area.

In addition to this finding from the literature, another significant point that was considered was that simulation projects are complex, large, and have a large amount of data, which makes them difficult to manage, consequently impacting their ultimate success (Balci 1989; Christensen et al. 1999; Sadowski and Grabau 1999; Skoogh and Johansson 2008). Balci (2011) stated that conducting large-scale complex modeling and simulation (M&S) projects continues to pose significant challenges for M&S engineers, project managers, and sponsoring organizations.

Considering this approach, this paper aims to propose a specific methodology for the management of DES projects based on the concepts of Project Management. In order to achieve this objective, an Action Research approach was taken by applying a project management methodology to a real simulation case in a high-tech company. As a result, the simulation methodology could be tested, evaluated and developed.

Our perspective is that Project Management might be useful for DES projects in helping to improve their management. This article is divided into six sections. The first section contextualizes the research topic. The second section gives a brief definition of the main topics of interest in this article which are DES and Project Management. Section three presents the research method used to develop the paper. Section four shows the application of the Action Research. Section five explores the results. Finally, section six exhibits the final conclusions and suggestions for future work.

2 LITERATURE REVIEW

2.1 Project Management (PM) in Discrete Event Simulation (DES)

As stated by Pereira et al. (2015), DES projects can be divided into three main phases which are: Conception, Implementation, and Analysis. The first phase, Conception, is responsible for the identification of the objectives of the simulation project, the definition of the system that will be studied, identification of the people involved in the process, construction of the conceptual model, validation of the conceptual model, data collection, as well as the timing, deadline and cost issues. At the second phase, Implementation, the main objective is to translate what was defined in the conceptual model into a computational model by using a specific simulator or language. From the data collected in the previous phase, it is possible to build the computational model. The model needs to be verified and validated through a range of tests, for example, a statistical test comparing historical data with the simulation data. Finally, at the third phase, Analysis, the analyst needs to prepare the experiments and scenarios to be investigated. So, based on what was defined at the beginning in the objectives step the analyst can use the computational model to determine how to achieve the study's objectives. This could be to increase productivity, to reduce waste or to reduce cost.

Among the few articles found in the literature discussing the management of DES projects, there are some authors who have presented some tips and advice for simulation analysts in order to help them to avoid some common mistakes during the development of simulation projects. These authors explore these recommendations based on their own experience over time in executing projects.

One of this articles is presented by Sturrock (2014). He discusses a lot of points that an analyst should be aware of in a simulation project. One point that he explores in his paper is the management of the project. According to the author, the analyst needs to manage the project and should not allow the project to manage him/her. A project that is completed just after the decision is made is of little value! It is part of an analyst's job to manage the simulation project so that it provides valuable insight in a timely fashion. All simulations are an approximation. Although a close approximation generally provides more accurate results, a rougher approximation can still provide valuable insights. If there is insufficient time to do the entire project well, then select a subset or a rougher approximation that you can do well in the time allotted. This should be reflected in the assumptions and simplifications of the functional specification.

Sturrock (2014) says that simulation is often a process of discovery. The analyst will gain knowledge as he/she goes from describing the system to the early simulation results. Often this new information may move the study in new directions. A certain amount of agility is appropriate in responding to such needs; however, too much agility can prevent project completion. At such times, the analyst must take the difficult step of telling the stakeholders "no" and deferring such requests to a later project phase. While no one likes to hear the word no, most stakeholders would prefer an honest no to a misleading yes. It is good to budget the time so that the important tasks will be completed and only then allow the project to explore some unanticipated directions.

Along the same lines, Hugan (2014) proposed a practical look at simulation project management. In his article, he has also shared advice for simulation analysts to help them achieve success in their projects. Hugan (2014) highlights the need for project boundaries. He says that simulations come in all shapes and sizes. As part of defining the scope of the modelling efforts, boundaries must be established to show where the model will start and stop with respect to the real world system. If the analyst is modelling a manufacturing facility, these boundaries might be the dock doors that supply raw materials and ship finished goods. If the analyst is modelling part of a manufacturing process, the boundaries could be the inbound and outbound materials for a specific department. By declaring the boundaries of the model, it helps avoid confusion in the project scope. For instance, the customer will not think that the analyst is modelling the trucks leaving the supplier's facility if the boundaries are clearly defined.

Balci (2011) proposed a discussion of how to successfully conduct large-scale modelling and simulation projects. He argues that a large-scale M&S application development requires many areas of expertise including simulation modeling methodology, software engineering, statistics, systems analysis, project management, and problem domain-specific knowledge. So, the simulation project manager needs to take care that appropriate people are selected to work on the project in order to ensure it is completed successfully.

Sturrock (2014) and Hugan (2014) identify several other points that could contribute to mistakes in a simulation project. These include the need to manage expectations, project completion, sign-off of the specification, understanding of the system, functional specification, data collection, documenting sources, relying on the specification, model structure, methods of validation, presentation of the results, documenting the path, use of video, model specification life-cycle, and controlling the scope.

Balci (2011) also discusses other important points for managing simulation projects, such as problem formulation, requirements engineering, conceptual modeling, architecting, design, implementation, integration, experimentation, presentation, certification, storage, and reuse. Also, these aspects are very important to be studied by analysts who are at the beginning of learning about how to perform simulation studies.

Harrel et al. (2000) identify a specific point that is important for DES projects: the projection of a new system requires more than simply identifying the system performance elements and objectives, it also requires a good understanding of how the elements of the system interact with each other and affect the overall performance of the system.

2.2 Project Management methodology: PMBOK®

In order to select a project management methodology for this work, interviews were conducted with some specialists in Discrete Event Simulation projects. These specialists have years of experience in developing and using simulation models. The specialists were asked what they felt was important to think about before starting a simulation project. They identified a number of points, such as:

- Signing of the contract between company and development team.
- Duration of the project.

- Selection of right and capable people who will work on the project.
- Total cost of the project.
- Definition of limits of the system.
- Purchase of software.
- Form of communication between members.

From these points raised by the specialists, we searched in the literature for project management methodologies that could be used to support a simulation project. The Project Management Body of Knowledge (PMBOK®) was found to potentially meet the requirements identified by the simulation experts .

According to PMBOK® (2013), the management processes of the project involves the study of the ten distinct areas of knowledge. Each area of knowledge represents a complete set of concepts, terms, and activities that make up a professional field, project management field or area of expertise. Project teams should use these ten areas of expertise, as appropriate, for their project. The areas of knowledge are:

1. Integration (identify, define, combine, unify, and coordinate the various processes and activities of the management process groups)
2. Scope (ensure that the project includes all the work needed to complete it successfully)
3. Time (manage the timeliness of the project, as it must end on the established date)
4. Cost (manage all project costs so that the approved budget is met)
5. Quality (satisfy the needs of the project, through the establishment of quality policies, objectives and responsibilities)
6. Human Resource (organize and manage the project team)
7. Communication (ensure that project information is generated, collected, distributed, stored, retrieved, and organized)
8. Risk (increase the likelihood and impact of positive events and reduce the likelihood and impact of negative events on the project)
9. Procurement (purchase products, services or results external to the project team)
10. Interested Parts (identify all persons, groups or organizations that may impact or be impacted by the project, analyze expectations and their impact on the project, and engage stakeholders in project decisions and implementation)

3 METHODOLOGY

3.1 Object of study

The object of this study is a simulation project which was developed in a manufacturing company with an external team of simulation analysts. The project was named Neotropic, with the purpose of developing computational models of two production lines, and proposing and executing improvement actions from the application of the techniques of DES and Value Stream Mapping. The company studied is located in Itajubá, Brazil, and produces electronic products composed of scanners, collectors, and tags of the brands "Sem Parar®" and "ConectCar®".

3.2 Action Research

The method used for conducting this research is Action Research. This choice was due to the nature of this research in which a problem is studied in practice and a possible solution based on theory is proposed. According to Mello et al. (2012), Action Research is a strategic method in production engineering that aims to produce knowledge and solve a practical problem. This requires action, both in practice and in research, so that it will have characteristics of both routine practice and scientific research.

For the application of Action Research in this paper we use the content and sequence constructed by Mello et al. (2012) which is composed by following steps: (1) Plan Action Research; (2) Data Collection; (3) Analyze Data and Plan Actions; (4) Implement Actions; (5) Evaluate Results and Generate Reports.

This type of research has two approaches of analysis of the results: a qualitative approach, in which the researcher seeks to understand the phenomena by observing, interpreting, and describing them (Mello et al. 2012); and a quantitative approach, in which it considers opinions and information that can be translated into numbers and analyzed statistically. It also allows the measurement of opinions, reactions, habits, and attitudes through a statistically representative sample (Peruchi 2014).

4 APPLICATION OF ACTION RESEARCH

As presented in the previous section, Action Research was the method used to conduct this research. The steps are briefly described in order to give more attention to the simulation methodology proposed. So, the first step is (1) Plan Action Research. In this initial phase, the object of study was visited by the development team and the objectives of the project were defined. In addition, we investigated how the team is accustomed to managing simulation projects. Thus, we advanced to the next step: (2) Data Collection. At the same time that the development team was collecting the data to execute the simulation model, such as times, arrivals, entities, etc., information about how the project was being managed and what aspects of the ten areas of knowledge were being considered in the project were also studied and collected. Based on this collected data, we could proceed to the next step: (3) Analyze Data and Plan Actions. From the data it can be seen that the development team used all ten areas of knowledge proposed by the PMBOK® (Integration, Scope, Time, Cost, Quality, Human Resource, Communication, Risk, Procurement, and Interested Parts), however, they were not aware that what they did was actually apply knowledge of the project management area in simulation. So, taking this as a basis, it was thought to propose this specific methodology for simulation projects, which would make it clear that it is part of the simulation and part of the project management area. Thereby, by studying the concepts of the project management and by analyzing what was being done in the simulation case, the simulation methodology was proposed. This is presented in the next sub-section. In the next step: (4) Implement Actions, the methodology was applied in the simulation case so the development team could use and evaluate it. Following this the final step was to: (5) Evaluate Results and Generate Reports..

4.1 Methodology for Management of Discrete Event Simulation Projects

The proposed methodology for managing DES projects follows the sequence of steps for conducting a simulation project proposed by Montevechi et al. (2010), in which it divides simulation projects into three stages: Conception, Implementation, and Analysis. and the methodology integrates the areas of Project Management and DES. The proposed methodology is depicted in Figure 1.

Following the methodology of Figure 1, we initially conduct meetings with the client to understand the objectives of the project, requirements, boundaries, definition of the system, among other initial concepts. With this in mind, the Project Charter is drawn up, in which it contains the information that was defined in accordance with the client. This term must be signed by both parties. In addition to the term, there is a Management Plan, in which more detailed issues are defined, such as: project duration, people who will be working on development, people who will be directly or indirectly involved in the project, workload and equipment to be acquired, such as simulators, software for statistical analysis and modeling, computers, timers, expenses in general, possible risks and changes, etc. These points must be deployed in the Management Plan, which must be aligned with the client and the development team. The contract then needs to be formally signed, thus initiating the development of the project.

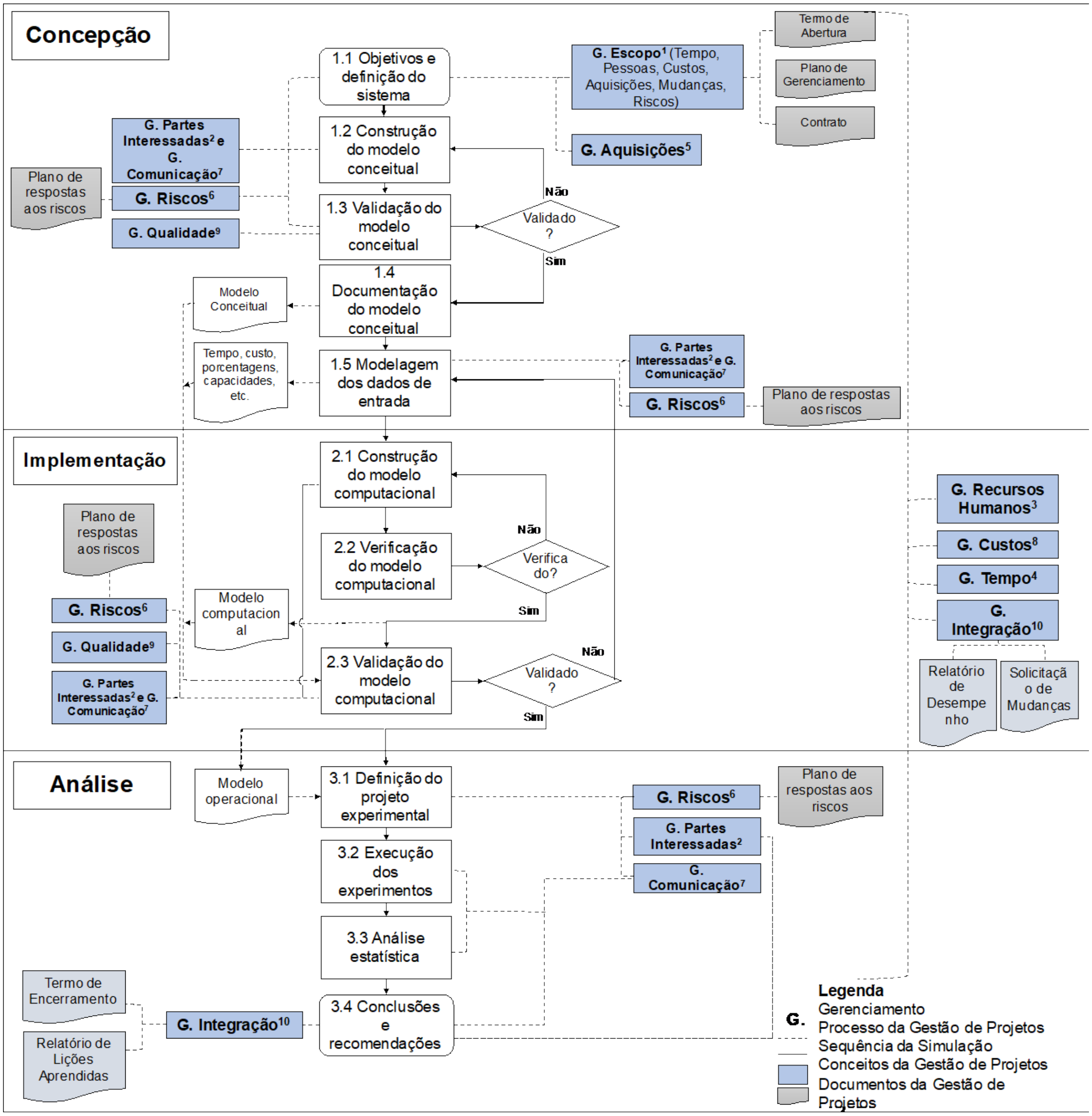

Figure 1: Methodology for the management of DES Projects.

In this phase of Conception, the Procurement area already takes place because a survey of all the materials that will be necessary to develop the simulation project and requests to purchase materials that are not available are a necessity. The materials include simulators, analysis software, and timers, . Thus, the project really begins and the conceptual model is constructed and its validation is carried out. At this moment, Interested Parties and Communication are two areas strongly related to these steps because in order to validate the conceptual model, simulation clients must ensure that the model conceptually represents reality. When the conceptual model is validated, the Quality area is employed, so in this moment the model can be used to develop the later stages. The Quality area helps to guarantee the model's validation. The team, in turn, does the documentation of this conceptual model, then begins the data collection stage to feed the computational model. At this moment, it is important the clients' participate and communicate among the members so that the model is appropriate for meeting the project's objectives. Finally, it should be remembered that the Risk area is an important activity because this ensures that even if a risk occurs, the project can continue. Thus, the Response Plan is the document that guides the next steps of the project.

In order to facilitate the understanding of what should be done in each stage, Table 1 is proposed, which summarizes the methodology. For each stage, items that summarize the discussion are defined. It should be remembered that for this simulation project the tools that were used were suitable for this project, therefore, the choice of these tools may vary according to the characteristics of the project under study. Thus, Table 1 serves as a basis to guide the important considerations to be taken in the management of each area of knowledge.

After the initial definitions and data collection, we follow to the next phase, Implementation, that corresponds to the development phase, in which the computational model is effectively developed. In the activities of construction, verification, and validation of the computational model, the management of Interested Parties and Communication should be considered. Besides statistical validation, it is also necessary to carry out a visual validation. This is usually carried out by means of demonstrations to the client. In this way, obtaining the validation of the computational model is the guarantee point for the DES that involves the Quality area. At the same time, there is the Risk area, which through the Risk Response Plan must be administered along with the development of the computational model.

The Human Resources, Costs, Time, and Integration areas are dimensions that must be executed throughout the project development, not only in the Implementation phase. Thus, verifying if the project is within the time and cost set are essential tasks in addition to considering the issue of people management. The Integration area also occurs at all stages, since it is responsible for making the connection between the other areas. These dimensions are monitored by the Project Manager. In the management of Integration, we suggest the use of Performance Reports and Request for changes, which can be applied as follow-up measures.

From the validated computational model, we proceed to the Analysis phase, as shown in Figure 1, in which the results of the simulation are analyzed. The development team conducts these analyses, defining the experimental design, and executing the experiments. They then conduct the statistical analyses and prepare the reports of the final results that will be delivered to the client. During these activities the Risk, Interested Parts, and Communication areas should be managed. Risk is necessary because changes can occur that impact the analysis of the results, so the team must use the Response Plan to deal with these situations.

The results are transferred to the client, that is, they must be well interpreted and there must be a good alignment and communication of both parties, so it requires the management of Interested Parties and Communication areas. Meetings may be held for the presentation of project conclusions. In the last activity of the Analysis phase, it is recommended to prepare the Closure term, which both parties sign, showing that the project was finalized. The Manager can also ask those involved in the project to respond to Lessons Learned Reports, so that with the experience gained by the members, it can be used as a basis for future projects, thus avoiding possible errors and rework. These documents are suggested in Integration management. The Human Resources, Costs, and Time managements happen until the closing activity so that it can be verified and confirmed that the scope was delivered as established at the beginning of the project.

The methodology described above was suggested based on the application of project management concepts in the development of the Neotropic project. With observation and study of how the project was executed, it is possible to suggest this methodology as a way to improve the management of DES projects.

Table 1: Methodology for project management of DES summarized in items.

Areas of Knowledge	Items
1. Scope	1.1 Meetings with client to understand the objectives of the project
	1.2 Elaboration of scope adding information as deadline, budget, and people (document)
	1.3 Agreement between client and team on the scope
	1.4 Control and monitor the execution of the project within the delimitation of the scope
2. Procurement	2.1 Check what needs to be bought
	2.2 Conduct the effective purchase of equipment
	2.3 Control and monitor the procurement process (document)
	2.4 Store the purchasing documents as receipts
3. Interested Parts	3.1 Identify the people involved into the project
	3.2 Define level of influence of each person and how they are directly related to the project
	3.3 Identify type of interest, power, and influence of people and define how to manage them
	3.4 Develop a strategy to manage conflicts between the members that can happen
4. Communication	4.1 Define members who are directly connected to the project
	4.2 Define model of communication between members of development team and client
	4.3 Establish communication tools (e-mail, telephone, meeting, web systems, etc.)
	4.4 Control and monitor whether the relationship between members is successful
	4.5 Drive improvements in communication model, if necessary
5. Human Resources	5.1 Interview people to fill job positions
	5.2 Conduct the procedures for hiring people
	5.3 Define the workload, responsibilities, and remuneration of each member
	5.4 Manage conflicts that can occur among members
6. Time	6.1 Elaborate the schedule of activities
	6.2 Define the main deliverables and deadlines for the client
	6.3 Detail tasks in subtasks and establish deadline to execute them
	6.4 Define the person responsible for executing each one of the tasks and subtasks
	6.5 Build network diagram which represent in a flowchart the main deliverables
	6.6 Develop Work Breakdown Structure (WBS) and Gantt chart
	6.7 Control and monitor the schedule during the development of the project
7. Cost	7.1 Elaborate detail of human resources costs
	7.2 Add expenses from procurement process and other expenses
	7.3 Control and monitor the process of detailing of the cost (document)
8. Risk	8.1 Identify the main risks of the project
	8.2 Categorize risks at levels: managerial, organizational, technical, and external
	8.3 Separate the risks between positive and negative
	8.4 Conduct SWOT analysis and Probability and Risk Matrix
	8.5 Prepare response plans for these risks, if they occur
9. Quality	9.1 Define the criteria which will measure the quality of the project
	9.2 Establish and apply measure tools
	9.3 Control and monitor the process
10. Integration	10.1 Elaborate the Project Charter and Management Plan (documents)
	10.2 Develop Follow-up and Monitoring Report (documents)
	10.3 Manage Change Request (document)
	10.4 Construct Closing Term and Lessons Learned Reports (documents)

5 RESULTS

As presented in section three, two approaches of analysis were used in this research: quantitative and qualitative. The quantitative analysis had the intention to validate the methodology by analyzing statistically the items proposed in Table 1. The analysis and findings are reported in details in Pereira (2017). Of all proposed items only two have not been statistically validated by the analysis: "5.2 - Conduct the procedures for hiring people" and "8.3 - Separate the risks between positive and negative".

The qualitative analysis consisted of identifying the opinion of the analysts with regard to the proposal developed in this article. Thus, two questionnaires were prepared and sent by e-mail to those members involved in the Neotropic project. The answers were summarized in the following list. These answers evaluated positively the methodology used.

- Research and development projects offer many complex problems and must be solved quickly, companies undergo constant and frequent changes, in this way, we must align with the company;
- Due to the fact that the company is from the electronic sector, products become obsolete fast, in this way, conceptual mapping may not represent the real process, since it has already undergone changes, therefore, new changes are necessary;
- Align project goals with company goals;
- The support of the team members and the company leaders were fundamental for the good development of the project;
- The monitoring of the tasks by the analysts and the collaboration of the employees in the proposed operational changes were important for the motivation of the trainees;
- Project management concepts helped to understand what could be improved;
- The planning was well thought out from the beginning; this is an important point to be considered;
- The fact of carrying out the weekly monitoring of planned and developed activities together with the well-structured communication contributed to the good progress of the project;
- The methodology aided during the development process by offering documents and tools that organized the project over its execution time;
- The methodology also helped in the organization and facilitation in sharing the documents with the members and clients;
- The methodology assisted in proving the results presented to the client, guaranteeing their satisfaction;
- A specific tool for solving a problem should not be established. First, is necessary to understand the problem and then select the appropriate tool for the solution of that problem;
- It is not advantageous to be held hostage by just one tool of Operational Research. The combination of different techniques can provide excellent results for the studied case;
- In real projects, a lot of changes can happen, unlike the theoretical problems of books. This project, for example, presented many changes. Some of them resulted in complex problems and altered the project schedule;
- Often, it is necessary to fight against the mentality of resistance to change by employees.

As can be observed by the previous list, the proposed methodology was well received by the respondents. The application of PMBOK® helped in the structuring of the processes of management of the simulation. The use of the PMBOK® made it possible to provide a guide for the simulation specialists, i.e. to start a simulation project it is necessary to think, for example, if the team has all the equipment and software needed to execute the project. It is necessary to think about the people who will be part of the project teams, how long they will be allocated to these activities, and how long it will take to execute each one. It is necessary to think about the total costs. In general, the use of the PMBOK® helped to improve the execution of the tasks to be performed by the analysts and mainly to facilitate the management of the project by the project manager.

It is important to say that PMBOK® is a generic guide that can be used to manage any project, not just in simulation projects. The PMBOK® can be very useful in many cases as it covers all areas of knowledge related to a project. However, this does not mean that every project should use this management structure, since many of the areas of knowledge discussed by the PMBOK® may not be useful to all project types.

There are some project types where the use of other methodologies is better than PMBOK® because they fit more effectively into the project in question. PMBOK® is more suited to large projects involving many people and requiring certain decisions to be made on the basis of consistent analysis.

6 CONCLUSION AND FURTHER WORK

This paper studies the area of Project Management within a real-life DES project. The paper aims to propose a specific management methodology for DES projects. The work was done in a high-tech company that produces scanners and tags. The case was monitored and Action Research was applied.

A review of the project and adopted methodology shows that members involved in the Neotropic project were positive about the approach taken. They provided some tips and advice that can help beginners and inexperienced analysts to avoid mistakes and rework.

The application of the PMBOK® could offer a better structure for the management of a DES project in helping analysts to think what points are important to be considered before a simulation project starts and during the execution of the tasks. In addition to offering a discussion on the ten areas of knowledge proposed by the PMBOK®, with this, analysts can take the proposal as the basis for the development of their project. They can also select the elements that they deem necessary for a specific case study. The application presented here is a generic way of developing simulation projects, but analysts can use this in any way they deem appropriate for their projects.

In conclusion, we have shown that it is possible to combine the principles of Project Management with a DES project. The PMBOK® approach brought improvements to the management process of the simulation project such as facilitation, streamlining, and organization of processes, seeking to ensure customer satisfaction. These are essential elements to improve the quality assurance and success of any project.

As future work, we suggest the replication of the proposal presented in different simulation projects in order to obtain knowledge that can improve this idea, incorporating new and different techniques, for example, software that can help the process management such as Gantt Chart and tasks follow-up that the manager can see the updates in real time. Also, we suggest that this proposal can be replicated in a different type of the simulation cases, for example, in services fields, in order to identify if it fits better in this type of simulation project.

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AUTHOR BIOGRAPHIES

TÁBATA FERNANDES PEREIRA is a Professor of Business Management at Federal University of Itajubá in Itabira campus. She is PhD in Industrial Engineering at Federal University of Itajubá with sandwich period at Texas A&M University as a Visiting Scholar. She received her Master degree in

Industrial Engineering from the Federal University of Itajubá, and BS in Information Systems from Research and Education Foundation of Itajubá. Her email is tabatafp@unifei.edu.br.

JOSÉ ARNALDO BARRA MONTEVECHI is a Titular Professor in Industrial Engineering at Federal University of Itajubá, in Brazil. He holds the degrees of Mechanical Engineer from Federal University of Itajubá and M.Sc. in Mechanical Engineer from Federal University of Santa Catarina, and Doctorate of Engineering from Polytechnic School of University of São Paulo. His research interest includes Operational Research, Simulation and Economic Engineering. His e-mail address is montevechi@unifei.edu.br.

MONA LIZA MOURA DE OLIVEIRA is PhD in Industrial Engineering at Federal University of Itajubá. She has a master's degree in Industrial Engineering and an undergraduate degree in Industrial Engineering which she also received from UNIFEI. Her email address is monaoli@yahoo.com.br.

STEWART ROBINSON is Dean and Professor of Management Science at Loughborough University, School of Business and Economics. Key areas of interest are conceptual modelling, model validation, output analysis and alternative simulation methods (discrete-event, system dynamics and agent based). Home page: www.stewartrobinson.co.uk. His email is s.l.robinson@lboro.ac.uk.

AMARNATH BANERJEE is a Professor and Corrie and Jim Furber '64 Faculty Fellow of Industrial and Systems Engineering at Texas A&M University. He received his Ph.D. in Industrial Engineering and Operations Research from the University of Illinois at Chicago, and BS in Computer Science from Birla Institute of Technology and Science, Pilani, India. His research interests are in modeling, simulation and visualization, with applications in manufacturing, health care, and information systems. His email address is banerjee@tamu.edu.

LUIZ FELIPE PUGLIESE is a Professor of Automation at Federal University of Itajubá in Itabira campus. He received his master degree in Electric Engineering from the Federal University of Itajubá, and BS in Control and Automation Engineering from Federal University of Itajubá. His email is luizfelipe.pugliese@unifei.edu.br.