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A STUDY ON THE MANAGEMENT OF A DISCRETE EVENT SIMULATION PROJECT IN A MANUFACTURING COMPANY WITH PMBOK®

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ABSTRACT

There has been an increase in the study of discrete simulation projects; however, literature lacks the topic of effectively managing these projects. Therefore, in this research, some principles from project management were applied in a discrete event simulation project. The action research method was used to implement the study. The ten knowledge areas from PMBOK®'s (2013) project management theory were applied to a simulation project, and a management plan was summarized for each area. Using a management plan to conduct the simulation has shown to be effective. Through organization and preparation, we have reduced risk, increased communication, developed two add-on packages for web information systems to manage the communication, effectively utilized resources, and most importantly, established clear project goals and deliverables. The simulation project is still in progress, therefore more comprehensive results are expected at project completion.

1 INTRODUCTION

In recent years, there has been an increasing emphasis on the study of discrete event simulation. The major research efforts have been focused on expanding the different applications of simulation. Examples include applications in manufacturing (Pena et al. 2016), healthcare (Levin and Garifullin 2015), services (Gogi, Tako, and Robinson 2016), and several others. One of the areas where there is limited research is the application of formal project management methods in the planning and execution of large scale simulation projects.

According to Sturrock (2014), development of a simulation project goes further than just building a computational model. It requires the ability to go beyond the knowledge of the specific simulation tool to develop a comprehensive model. The primary challenge is to do this correctly and effectively (Balci 1989).

The experiences of simulation projects and simulation project managers have been studied by several researchers. The point of view of a simulation project manager in the form of tips to be successful in simulation projects is discussed in Sturrock (2014). The author considers simulation as a process of discovery, referencing the popular saying: “If you don’t know where you are going, how do you know when you arrive there?”

Hugan (2014), based on his own experience in project management, discusses the common and uncommon aspects that lead simulation analysts to make mistakes during the execution of simulation projects. Sadowski and Grabau (1999), based on their professional experiences, have published a study providing several suggestions to achieve success in simulation practice. Balci has provided insights into how to conduct simulation projects (Balci 1989). Over the years, he has studied the life cycle of simulation projects highlighting the steps that should be followed, and provided suggestions to achieve good results at the end of each project. Jessen et al. (2015) discussed the usage of different approaches for supporting project management of plant engineering projects, in order to be supported by adequate methods for the estimation of project risks and uncertainties.

The above authors describe ways to successfully execute a simulation project, they provide suggestions based on their experience and missteps while working on projects in the past, and they also elaborate on a proper definition of the project scope at the start of a project. Based on those aspects and the lack in the literature of researches that address topics as discrete event simulation and project management, in this paper we look in to the management process of a discrete event simulation project.

The objective employs the general principle recommended in the PMBOK® to integrate with simulation methods for improving the project execution performance. To achieve this goal we developed a management plan of the steps involved in the project management model using the knowledge areas proposed by PMBOK®.

The goal of this paper is not to conduct a simulation model with modeling, verification, and validation phases, indeed some aspects around a simulation project are been considered. Our intention is to manage a discrete event simulation project using principles from project management in which is being conducting in a real simulation case.

Furthermore, the action research method was used, following the steps proposed by Coughlan and Coghlan (2002). The action research is methodology that addresses a study that will analyze a real problem or research question, and from that point propose a solution for this research question. This study aims to answer the following research question: “How to manage simulation projects for improving the project execution performance?”

This article is divided into five sections. The first section contextualizes the topic of this research. Section 2 shows the basic and necessary concepts about discrete event simulation and project management. The third section shows the research method action research. The fourth section discusses the application of the method as well as the results of a study. Finally, Section 5 presents the conclusions of this research.

2 LITERATURE REVIEW

2.1 Discrete Event Simulation (DES)

In the last decade, Discrete Event Simulation (DES) has become a more popular technique for designing models of production systems that simulate actual operations and examine different scenarios, keeping control on cost and time by reducing the need to carry out real-life experiments, and employed to aid decision-making (Ahmed, Scoble, and Dunbar 2016, Pereira et al. 2015, Rekapalli and Martinez 2010). Discrete Event Simulation is one of the most frequently used techniques for the analysis and design of manufacturing systems (Anglani et al. 2002).

Simulation is the imitation of the operation of a real-world process or system over time. The behavior of a system as it evolves over time can be studied by developing a simulation model (Shawki et al. 2015). Discrete event simulation is a form of computer-based modeling that provides an intuitive and flexible approach to representing complex systems (Karnon et al. 2012) .

According to Botín, Campbell, and Guzmán (2015), DES is a simulation method that proceeds through discrete time steps where the state of the system changes due to the occurrence of an event. DES models may be defined as a simplified representation of a real-life system which allows one to understand

and solve a problem through an experimental approach. In DES, the experience of individuals is modeled over time in terms of the events that occur and the consequences of those events (Caro, Möller, and Getsios 2010). In addition, DES can incorporate the effects of system variability using probability distributions and estimated parameters to characterize the system variables bearing uncertainty and risk.

There are some procedures in literature which aid the analyst in the development of simulation projects (Montevechi et al. 2015). The works of, Mitroff et al. (1974), Banks (1998), and Balci (2011) illustrate the systematics of the life cycle of a project, dividing the project into tasks which the analyst should follow to build a simulation model.

Pereira et al. (2015) articulate that most simulation projects can be divided into three steps: conception, implementation and analysis. The conception phase defines the objectives of the simulation and includes the development of an abstract model of the real word system under study, which is called conceptual model. In the implementation phase, a computer model is built based on the conceptual model using a simulation software and, hence, it consists of the translation of the real-world systems into a computational specific model. Finally, in the analysis phase the results from the outputs generated from the simulation runs are analyzed (Sloot, Pimentel, and Hertzberger 1998, Pereira et al. 2015). According to Balci (2011), the key for success in a simulation study relies on following a structured, complete and well organized methodology.

2.2 Project Management (PM)

In recent decades organizations have been interested in increasing the success rates of projects and ensure delivery of results studying and developing projects, programs and portfolios, to have a more efficient strategy advantage (Serra and Kunc 2015, Papillon 2016).

As Klein, Biesenthal, and Dehlin (2015) the Project Management area is too complex, so that's why it has a big field of investigation and create opportunities to contribute to a constantly changing environment. Given this importance it is interest to understand first what the definition of project is.

According to PMBOK® (2013) "a project is a temporary endeavor undertaken to create a unique product, service, or result". A project can create: A product that can be either a component of another item, an enhancement of an item, or an end item in itself; A service or a capability to perform a service (e.g., a business function that supports production or distribution); An improvement in the existing product or service lines (e.g., A Six Sigma project undertaken to reduce defects); or A result, such as an outcome or document (e.g., a research project that develops knowledge that can be used to determine whether a trend exists or a new process will benefit society).

Turner and Müller (2005) claims that Project Management is a disciplined application of knowledge, abilities, tools and techniques of activities to answer the requirements of a project. Also, Project Management is the application of knowledge, skills, tools, and techniques to project activities to meet the project requirements (PMBOK® 2013), it is accomplished through the appropriate application and integration of the 47 logically grouped project management processes, which are categorized into five Process Groups. These five Process Groups are Initiating, Planning, Executing, Monitoring and Controlling, and Closing.

The 47 project management processes identified in the PMBOK® are further grouped into ten separate Knowledge Areas. A Knowledge Area represents a complete set of concepts, terms, and activities that make up a professional field, project management field, or area of specialization. These ten Knowledge Areas are used on most projects most of the time. Project teams should utilize these ten Knowledge Areas and other Knowledge Areas, as appropriate, for their specific project. The Knowledge Areas are: Project Integration Management, Project Scope Management, Project Time Management, Project Quality Management, Project Human Resource Management, Project Communications Management, Project Risk Management, Project Procurement Management and Project Stakeholder Management.

3 RESEARCH METHOD: ACTION RESEARCH (AR)

According to Coughlan and Coghlan (2002) and Foster (1972), Action Research is a Research *in* action, rather than research *about* action; Participative; Concurrent with action; A sequence of events and an approach to problem solving. Coghlan and Brannick (2001) claim AR is appropriate when the research question is related to describing several actions over time in a given group, community or organization, understanding as a member of a study how and why their action can improve the working of some aspects of a system, and understanding the process of change or improvements in order to learn from it. At this point we decided to use this research method to conduct our study. Given a problem, we follow the steps of AR, study the problem, and develop an action plan aimed at solving the research question. Then, we implemented this action plan in a real system and evaluate it.

3.1 Action Research

Action Research covers many forms of action-oriented research, and indicates diversity in theory and practice among action researches. So, it is desirable to provide a wide choice for potential action researchers about the appropriate research questions (Coughlan and Coghlan 2002). They specify that the AR cycle comprises of three types of steps: (1) A pre-step – to understand context and purpose; (2) Six main steps – to gather, feedback and analyze data, and to plan, implement and evaluate action; and (3) meta-step for monitoring.

4 APPLICATION OF ACTION RESEARCH

In this section the application of Action Research and the steps proposed by Coughlan and Coghlan (2002) are showed.

4.1 Plan Action Research

This first step of AR is divided into three tasks that are explained below:

Definition of context and purpose: consists in define and identify the research field, interested people and their expectations, diagnosis of the situation, priority of the problems, and eventual actions. Literature lacks the topic of managing simulation projects, while they mention procedures for conducting simulation projects, they do not discuss the management of such projects. Additionally, we found some authors discussing how to achieve success in a simulation project, which can be described as how to develop good projects in this area. Based on these aspects we have applied some principles from project management into a discrete event simulation project. We intend to offer some important considerations on this topic in order to aid researchers in both areas, discrete event simulation and project management, with the development of this study.

The computational model as the central component of a project, and there are some aspects as human resources, integration, costs, risks, acquisition, interested parties, communication, scope, time, and quality, these aspects should be considered by project managers at the start of a simulation project. The objective of management of simulation projects is to deal with all these aspects while the simulation is going on.

Definition of the theoretical conceptual structure: this step is responsible for establishing the theoretical conceptual structure guiding the mapping of the topics. The theoretical structure was defined earlier in section 2 where the basic concepts on discrete event simulation and project management were discussed.

Selection of analysis unit and forms of the collected data: this step is divided into two parts. The first part is the definition of analysis unit. The unit source in this study is part of a multinational company called Honeywell® that offers products and services in different markets: aerospace, electronics, industrial, security, automotive, energy, among others. Founded in 1904 by Mark Honeywell, the company now has 127,000 employees in different centers spread across all continents (HONEYWELL

2016). The Honeywell® center used in this study is localized in Itajubá, a city in southeastern Brazil. This center manufactures electronic products comprised of scanners, collectors and RFID (Radio-Frequency Identification) tags with brand names "Sem Parar®" and "ConectCar®". The desire of Honeywell's center director is to improve their production process, this is the main reason that has led to the development of this study. Honeywell has forged a close partnership with Federal University of Itajubá. At the beginning of the project, the faculty leading from the University and the Honeywell's center director had defined the project scope, and part of the definition of the context and purpose. It was decided that the project should improve two production lines, one line is responsible for the production of scanners, and other line is responsible for the production of RFID tags. Some of the aspects will be explained in a later section. The data collect process from the real system was selected utilizing different methods, including historical data, timing, and meetings.

4.2 Data Collection

The project started in January 2015. After the first meeting with the center director, the University faculty started to assemble the necessary resources for the development of the project. Weekly meetings were scheduled between the coordinators of the production lines (from the company) and the development team (from the university) to map processes and identify boundaries of the system. It made possible to identify and collect data needed to conduct the study.

4.3 Data Analysis and Action Planning

After the data collection step, the Action Plan for this simulation project was developed. This Action Plan intended to address all those ten knowledge areas proposed by PMBOK® summarizing all important information in one action for each knowledge area, as is showed in Table 1.

Table 1: Action Plan for a simulation project.

#	Actions	Knowledge areas
1	Definition of main issues and deliverables of the project	Project Time Management
2	Definition of the development team	Project Human Resources Management
3	Definition of the development team workload	Project Time Management
4	Definition of requirements	Project Scope Management
5	Preparation of procurement plan (software and products)	Project Procurement Management
6	Identification of the stakeholders	Project Stakeholder Management
7	Definition of the form of communication between the development team and stakeholder, and members of the development team	Project Communication Management
8	Setting the compensation for services of the development team members	Project Cost Management
9	Preparation of project integration plan	Project Integration Management
10	Development of the project risk plan	Project Risk Management
11	Definition of the model quality control	Project Quality Management

4.4 Implement Actions

In this section the implementation of the Action Plan in a real simulation project is described based on the principles from PMBOK®. The first action "Definition of main issues and deliverables of the project" is suggest to define the issues related to timeline and deliverables of the project, related with Knowledge area called Time Management. Table 2 shows the main issues and timeline for the simulation project defined in close collaboration with the company.

Table 2: Main issue of simulation project.

#	Main issues	Start time
1	Beginning of the project	February, 2015
2	Validation of conceptual models (IDEF-SIM and *Lean*)	October, 2015
3	Validation of computer model	February, 2016
4	Analysis of results	December, 2016
5	Final issue of computer models, documents and reports	February, 2017

The second action consists of defining the development team, as Table 3 shows. This action is related to Project Human Resources Management. The project coordinator from the University chose this structure of development team based on the abilities required to develop the project tasks. The position of coordinator is the faculty contact from the university. The tutors are faculty that specialized in discrete event simulation, process analysis and mapping, and lean manufacturing. The information technology professionals are responsible for the configuration and implementation of all electronic information used in the project. Finally, the trainees are responsible for execution of the tasks and collection of data.

Table 3: Development team.

Development team		
Position	**Function/Responsibility**	**Quantity**
Coordinator/ project manager	Coordinate all activities of the project	1
Tutors	Guide the implementation of activities	2
Information Technology Professionals	Develop/implement the necessary tools to conduct the project	3
Trainees	Execute the activities and collect the data	2

The third action "Definition of the development team workload" was related to Project Time Management. Each group member has a different time schedule as is presented in Table 4. For example, all the members are scheduled to work in this project during over 24 months, the Coordinator has a week workload of 3 hours per week, while the trainees have a week workload of 30 hour per week.

Table 4: Workload development team.

Development team workload					
Position	**Time (months)**	**workload (hrs/week)**	**workload (hrs/month)**	**workload (hrs/annual)**	**workload (hrs/total)**
Coordinator	24	3	12	144	288
Tutors	24	2	8	96	192
Information Technology Professional	24	2	8	96	192
Trainees	24	30	120	1140	2880

The fourth action is related to the definition of requirements, this action is linked with the Project Scope Management in which defines aspects about the scope. In other words, the intention is to identify simulation questions and resources that can be used to analyze the design limitations of the project. Those aspects are including in a formal document named Develop Project Charter. Thus, a high level definition and product requirements of the simulation project was developed. Table 5 shows this definitions.

Table 5: High level definition and product requirements.

High level definition and product requirements
The Neotropic project is a partnership between Honeywell® and Federal University of Itajubá. The main objective to use decision-making tools such as discrete event simulation and lean manufacturing to propose improvements in the company's production processes. After conducting this study, we will obtain two computational models as the final product. One model will represent the reality of the company today, as is working with its resources. The other model will include the proposed improvements after analysis. In addition to these computer models, deliverables will include the analysis conducted at different steps in the project as well as a report describing the steps that were followed.

The fifth action is the preparation of the procurement plan (software and products). The Project Procurement Management includes the needed processes to purchase or acquire products or services from outside the project development team. Hence, a list was prepared (Table 6) with all needed tools to conduct the project. The development team already possessed many of those tools which means that the rest of the tools had to be acquired or purchased.

Table 6: Project procurement management.

Tools	**Quantity**	**Status**
Simulators (Promodel®, Simio®, Arena®, FlexSim®)	1	Development team already has
Camera (photo and movie)	1	Purchase
Stopwatches	2	Purchase
Notebooks	2	Development team already has
Statistical software tools	2	Purchase
External HD	1	Purchase
Information management systems	2	Development team already has

The sixth action of the plan is related to the identification of the stakeholders, and this action does part of Project Stakeholder Management. In this step, a Coordinator is necessary and will be responsible to manage all activities of the project in parallel with the development team. All information was configured with the company's leadership and can be seen in Table 7.

Table 7: Definition of stakeholders.

Stakeholders		
Position	**Function/Responsibility**	**Quantity**
Coordinator	Coordinate all activities of the project in parallel with the development team	1
Production leaders	Answer questions necessary for the development team	3
Professional from national purchases	Provide information requested by the development team	1
Professional from human resources	Provide information requested by the development team	2
Professional from sales	Provide information requested by the development team	2
Professional from inventory	Provide information requested by the development team	1
Staff from production lines	Provide process information	How many required

The seventh action consists of defining the form of communication between the development team and stakeholder, part of the Project Communication Management, that includes the processes required to ensure timely and appropriate planning, collection, creation, distribution, storage, retrieval, management, control, monitoring, and the ultimate disposal of project information. Project managers spend most of their time communicating with team members and other project stakeholders, whether they are internal or external to the organization. A structure was developed in order to identify communication pattern among members of the project. This structure is showed in Figure 1.

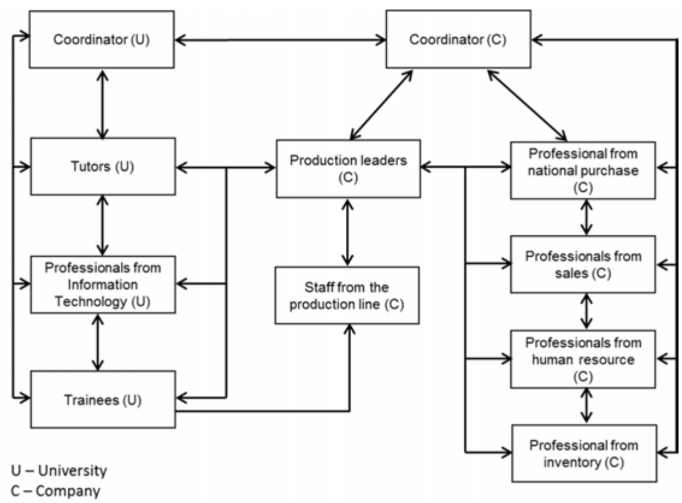

Figure 1: Project communication structure.

The eighth action of this plan is set to the compensation for services of the development team members, this action does part of Project Cost Management. Due to reasons of confidentiality, this information is hidden as well as the names of employees and their respective functions.

The ninth action is related to the preparation of project integration plan, part of Project Integration Management. According to PMBOK® (2013) in the project management context, integration includes characteristics of unification, consolidation, communication, and integrative actions that are crucial to controlled project execution through completion, successfully managing stakeholder expectations, and meeting requirements. Project Integration Management includes making choices about resource allocation, making trade-offs among competing objectives and alternatives, and managing the interdependencies among the project management knowledge areas.

This action was developed into two parts. One is linked with the fourth action, definition of requirements, where the objectives of the simulation was defined in an official document named Develop Project Charter. This part is related to knowledge area of Project Scope Management. The second part is still under development in which is related to the monitoring of project, it corresponds to the seventh action, Project Communication Management, where the results of the project can be followed in each meeting between the stakeholders and the members of the project.

Action number ten is the development of the Project Risk Management. This includes the processes of conducting risk management planning, identification, analysis, response planning, and controlling risk on a project. The objectives of Project Risk Management are to increase the likelihood and impact of positive events, and decrease likelihood and impact of negative events in the project (PMBOK® 2013). Table 8 lists the possible risks that could exist in the project, and possible mitigation strategies to solve these risks.

Table 8: Possible risks in the simulation project.

Risks	Mitigation Strategies
Change in the production line	Evaluate the impact in the computer model
Lack of members in the development team	Immediate relocation of members
Solicitation of changes by the stakeholder	Evaluate the impact in the computer model
Market risks	Using historical data

Finally, action number 11 "Definition of the model quality control" does part of the Project Quality Management. As this project is still being developed some aspects from Project Quality Management couldn't be achieved for now.

4.5 Evaluate Results and Generate Reports

By applying project management principles to a simulation project, we have been able to consider aspects of the project that have not been considered in the past, which means that we tried to do the integration approaching to these topics. A summary of management plan for each area of knowledge were elaborated.

As among some results, Project Communication Management helped in the development of a good structure to manage communication between project members and stakeholders. At this point, two add-on packages for web information systems were implemented in order to help Communication Management. Another result that can be highlighted here is the development of a formal document called Develop Project Charter in which includes information about Project Scope Management.

This project is still being developed, which prevents us from collecting all the data and writing the results completely. However what the development of this project has demonstrated is that some interesting applications can be addressed involving these two areas here studied. Good results are being expected by both of coordination. And what we can ensure for while is that this project is being developed well following concepts from project management proposed by PMBOK®.

4.6 Monitoring

The monitoring of this project is being developed in each of the ten areas of knowledge where is possible to follow the steps and verify the conduction of the tasks, and if necessary, some adjustments are implemented during the week meetings by coordinators.

5 CONCLUSIONS

Discrete event simulation is a comprehensively explored area in the literature, however when is considered the approach of project management in this area, there are no papers related to these two research fields. Additionally, what are possible to verify in the literature is that some authors proposes some advices to simulation analysts in order to avoid mistakes that can happen during the project or some tips to help analysts to achieve success in the conduction of the simulation project.

From this point, our paper tried to look for the management process of a discrete event simulation project. Thus, general principles recommended in the PMBOK® to integrate with simulation methods were employed. Our paper intended to propose a possible answer for our research question which was: "How to manage simulation projects for improving the project execution performance?".

To achieve this goal, an Action Plan was developed approaching a short integration based on principles of project management proposed by PMBOK® to this simulation project, applied in real simulation project at a manufacturing company named Honeywell® located in southeastern Brazil. Data were collect using some techniques as historical data, timing, and meetings.

As results of this paper, the specifications from this simulation project were considered, so the joint research areas were proposed, taking principles of project management and applying it to simulation project. Some consistent results were also obtained, as the development of a formal document called Project Charter to Project Scope Management; two add-on packages for web information systems specially designed for simulation projects were implemented in order to offer a good communication tool among members; the identification of possible risks that can interfere during the project and some strategies to avoid them; and most importantly, established clear project goals and deliverables.

The simulation project is still in progress, therefore more comprehensive results are expected at project completion, which will be discussed in a forthcoming article. Nevertheless, the findings of this study demonstrate the potential use of project management principles to discrete event simulation in order to improve the performance of the projects.

The main contribution of our study is related with the investigation of a new topic rarely addressed in the literature with the intention to help simulation analysis and practitioners interested to discuss on this approach. As we have showed, good results can be obtained with the integration of these two research areas. In this context, for future works we suggest a depth study to each one of the ten knowledge areas proposed by PMBOK®.

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