OULUN YLIOPISTO
UNIVERSITY of OULU

FACULTY OF TECHNOLOGY

The Use of Simulation to Learn Project Business in a Complex Context

Amaia Alcelay Losáñez

Degree's thesis (PFG)

Department of Industrial Engineering and Management

May 2015, Oulu

ABSTRACT FOR THESIS

University of Oulu Faculty of Technology

Degree Programme	Major Subject
Degree of Engineering in Industrial Technologies	
Author	**Thesis Supervisor**
Amaia Alcelay Losáñez	Kujala J., Prof.

Title of Thesis

The Use of Simulation to Learn Project Business in a Complex Context

Major Subject	Type of Thesis	Submission Date	Number of Pages
Quality and Project Management	Degree's Thesis	May 2015	52

Abstract

This paper presents how the use of simulation can provide benefits to learn project business in nowadays world's complex context. This last decade, due to the fast technological advances and the rising globalization, markets are becoming more and more competitive, and this drives companies to increase their interest in planning and implementing specific projects, as they strive to achieve corporate goals. This resulted on various standards emerging around project management and an increase in the degree of professionalism. However, projects still continue to fail due to the increasing complexity of the projects or an underestimation of the projects complexity. The aim of the framework is to presents after a literature review, what a project business is, what complexity means in this context, and how simulation can help to avoid the gaps of nowadays. With this information a proper simulation model is designed using the software *Anylogic*. The model is based in a project process network and it's mainly focused on buffers allocation, resources, quality, budget and time management. Once the model was done has been validated in a workshop through a form the participants filled after interacting with the software and the models. With that feedback it has been possible to evaluate how students feel about using simulation as a teaching tool and show how the literature references were right and closely connected with the results obtained.

Additional Information

Keywords: Simulation based training, project management, AnyLogic, project network, complexities, education.

Acknowledgements

I wish to express my sincere thanks to Professor Jaakko Kujala, for giving me such an interesting topic for my degree thesis, and I am extremely thankful and indebted to him for sharing expertise, and sincere and valuable guidance and encouragement extended to me. I have learned to plan my time and to schedule along the semester all the research and activities to be conducted. Besides this, I had fun working on it and I believe to have gained a deep understanding about the theory.

Secondly, I place on record, my sincere thank you to Tapio Lassi, who has helped me through all the simulations and we have fight together against AnyLogic. I wouldn't have been possible without his continuous encouragement.

I would also like to thank all the exchange students for the discussions, for the sleepless nights we were working together before deadlines, and for all the fun we have had in the last four months. I thank you for not only sharing with me your valuable time and thoughts but also motivate me throughout the duration of this spectacular experience here in Oulu.

I also thank my family and friends for the unceasing encouragement, support and attention during these 4 years of my university studies.

Finally, I place on record, my sense of gratitude to one and all that people who directly or indirectly, have let their hand in this venture.

Contents

1. Introduction

1.1. Background and motivation of the research

Nowadays the world goes fast forward due to the rapid technological advances and the rising globalization. This leads markets becoming more and more competitive, and drives companies to increase their interest in planning and implementing specific projects, as they work towards achieving corporate goals.

During the past 10 years, various standards have emerged and have helped to increase the degree of professionalism of project management. This standards and certificates are moving now towards becoming the quasi-standard of project management worldwide. The problem is that projects still continue to fail although the implementation of these standards, due to the increasing complexity of the projects and an underestimation of the projects complexity.

That is why can be seen that there is still a huge gap between how the project management skills are taught and how later in the real projects are developed, so education in project management needs to be improved (Freeman & Dumas , 1989). The education in this field needs to be renewed taking the complex attributes and the actuality of projects into account, with new perspective. That is why advantage should be taken from those new technologies and facilities available, and focuses on applying the theory acquired through the traditional educational methods to more practical and realistic situations taking advantage of the newest tools, such as computer software's and simulations.

"Simulation is the tool to increase the effectiveness of the learning environment." (Wateridge, 1997). Simulation-based training has been used in multiple disciplines and it is proved that helps creating more realistic and experimental learning environments. Seeing that, a research will be done to discover which are the main reasons of the failure of the projects nowadays, and later implement those lack of knowledge's in a simulation model so as when running it, students acquire the necessary capabilities to deal with them in the real world.

1.2. Research objective

The aim of the research is to design and implement part of a simulation model that can be used to implement complex project processes. For that, a research is necessary to collect the required information to build the desired model. So as to conduct the research, the next research questions will help to obtain information and discover which should be the main focus of the simulation models and which learning goals they should have to guarantee the success of the project management teaching.

RQ1: ***How simulation supports management education?***
RQ2: ***Which are the key challenges/attributes that simulation must take into account in the context of complex project business?***

The first research question is focused in finding out which are the main problems of project management education nowadays, and how simulation can fix those gaps. At the beginning a study about basic project business and project management is going to be done to settle the context and the scope of the theme. Later, advantages and benefits of simulation provided by simulation based training will be reviewed and will help to find out if this tool provides benefits and covers the gaps nowadays project management education has.

In the other hand, the second research question refers to those attributes that the simulation must have so as to cover all the challenges a complex project business has. An exhaustive research must be done, then to apply all the necessary characteristics to the simulation models that are going to be built as an effective learning tool for teaching project business.

With these literature, will be easier to design a simulation model that covers the aim of the thesis, implement a model that can be used in a complex environment of project management.

1.3. Scope of the thesis

During the research in the thesis, the use of simulation to learn project management is going to be analyzed in order to verify if it is a useful tool to cover this field. The focus

is going to be fundamentally in finding out if a simulation exercise can enhance the project management learning, using the AnyLogic software. So the final aim is going to be designing a simulation model that later will be validated in a Project Management Workshop in the University of Oulu, in May 2015. For this, a literature research is done for later developing the proper simulation model including the characteristics and attributes found. The students that will complete the assignment will be afterwards asked to fill a form to give feedback about the exercise and evaluate how they feel about using simulation as a tool for project management education and also ask them how they would improve the model.

The main reason for choosing this software for developing the models was to try to implement the system with the agent based approach. This feature gives the opportunity to implement different relations between the agents that could enable to visualize the impact of the conflict in goals, values and cultural norms in the project team. As it was the first time working with this software and before implementing such attributes and relations to the model, it is necessary to have implemented the basic lay out, the activities and its characteristic figuring out how to deal and interact between them. At the end, and because of the lack of time, the scope of the models has been limited to develop this basic model by the discrete event approach implementing most of the characteristics related to buffers, salaries, paychecks, workers, resources, etc., but not anything referred to those organizational complexities using the agent based approach. So underline that the model that is going to be design is not going to simulate all the project network that will be mentioned during the literature, but will only be the start point for in a future implement a model that can be used in complex project processes.

1.4. Structure of the thesis

The thesis is structured in four main chapters that will help to develop the research that later will lead to the design of the simulation model and it’s afterwards validation in the workshop. During the first chapter an introduction to the topic, to the problem and to the theoretical background is done so as to facilitate the reader to be familiar with the working themes.

The second chapter will develop all the necessary literature, helped by the research questions, so there will be two main topics. One referring to the use of simulation in the

management education, and the other one about the characteristics and managerial challenges of a project business. Research through these themes will help later to have the proper information to design the desired simulation model.

That design is going to be explained during the third chapter. Here the characteristics a simulation model in complex environment should have are going to be pointed out, so later the design is going to be built from the theory. The learning goals the model should have are going to be listed and later on, the designed models characteristics are going to be explained. To conclude this chapter, how the validation of the model has been done is going to be exposed and the results obtained analyzed.

Finally, and in the fourth chapter, a discussion is going to be hold linking the researched literature with the obtained practice model. To sum up, some conclusions will be developed and how to continue ahead through the model will also be discussed.

1.5. Research approach

The aim of the research is to design and perform part of a simulation model that can be used to implement complex project processes. The simulation exercise has practical relevance as the objective is to enhance the project management education through it. To validate these models, a group of students will test them and give their feedback about the exercise. With this, conclusions will be drawn and applied to the exercise in order to improve the models for the future.

With this structure, that a **constructive research approac**h is used can be underlined. The common factor of a constructive study is that its aim is to solve real world problems by developing a solution that has both practical and theoretical relevance (Kasanen;Lukka;& Siitonen, 1993). The constructive research approach has been divided into six phases (Kasanen;Lukka;& Siitonen, 1993) shown in the next figure, and then related to the, main chapters of this thesis. In this case the solution or the construction is to design a simulation model that will fit all the characteristics required to cover the project management teaching goals. After that the workshop will help to validate the model.

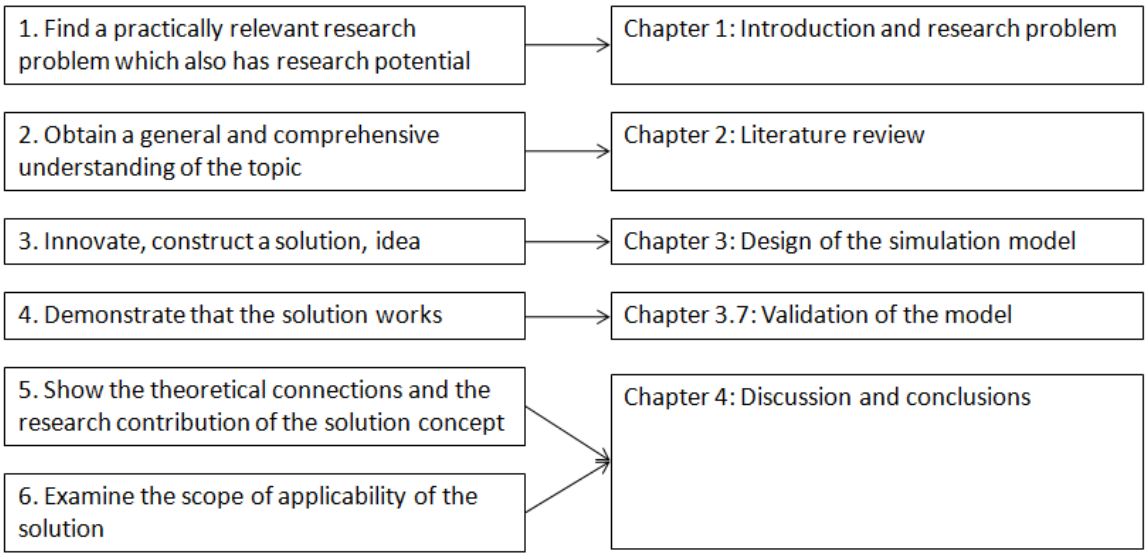


Figure 1: Steps of constructive research and relation to the thesis structure

Validity is about conducting properly the research and is a property of the testing procedure (Kasanen;Lukka;& Siitonen, 1993). Testing the functionality of the solution is usually a way of providing the information needed for making the final conclusions about the research. In this case the workshop will be the way of validating the simulation model, after the students interact with the model and give their feedback.

2. Literature review

In this second chapter all the literature obtained though the research is going to be presented. Firstly making reference to the use of simulation in the management education, and later explaining the characteristics and managerial challenges of a project business. At the end a summary will collect the main ideas that later will help to properly design the desired simulation model.

2.1. Use of simulation in management education

About the use of simulation in management education, first an introduction about the basics of project business and project management are going to be discussed. Later, what simulation means and how can be implemented for educational purposes are going to be presented. Finally, how this tool can improve the results of the teaching of project management and which are its advantages are going to be explained.

2.1.1. Basic of project business and project management

Companies do business in order to succeed in the market and fulfill the expectations of their owners and other stakeholders. These expectations/objectives in a company are often related to its survival or success. They can be related to fulfilling the expectations of the owner, customers, or other stakeholders for growth, profitability, or fulfillment of some type of no commercial values (Kujala;Martinsuo;& Artto, 2011).

So as to reach these goals, **project business,** the part of a business that relates directly or indirectly to projects (Artto & Wikström, 2005) and is nowadays really applied with the purpose of achieving objectives of a firm or several firms. Project business can involve delivery projects, which involves delivering value-added solutions to external customers, and internal projects, which develop solutions for the companies own business.

A **project** is a unique entity formed of complex and interrelated activities, having a predefined goal that must be completed by a specific time (a project does not last forever, defined beginning and end in time), within budget, and according to specification (Kujala;Martinsuo;& Artto, 2011). According to the Project Management Institute, a project is a temporary endeavor undertaken to create a unique product, service or result (PMBOK, 2013). When a project is defined as unique is because it is not a routine operation, but a specific set of operations designed to accomplish a singular goal. In consequence, a project team often includes people who do not usually work together, sometimes from different specialties, organizations and across multiple geographies, to reach the highest performance.

There are mainly two types of projects, research project and development project. The first one refers to those that create or find applicable knowledge and is difficult to predict which will be the benefits obtained. The second applies knowledge to create new products, services, solutions, competences or functionalities, or is also used to enhance old ones. In this kind of projects the uncertainty is lower and is easier to predict the results.

Inside a project there are some concepts that really need to be taken into account so as to understand what it is going on and how it works. Those are the most important ones. A **program** implies a large project or an entity formed by several projects with a common goal. A **contract** is especially used to describe projects in the construction industry and deals with fixed price and complete deliveries. An **assignment** is a task given by one party to another to be accomplished according to some predetermined terms. The **task force or team** is a group of people brought together to accomplish a certain task. A **job** can be accomplished thought a project. A **task** is the mission or the reason for which the project exists. (Kujala;Martinsuo;& Artto, 2011).

The main goals/requirements in a project include time, cost/resources and scope limitations that are needed to be reached to achieve the success and competitiveness. This is due to the stakeholders requirements, as they limit the time and the cost budget of the project. Therefore, the budget limits the final cost of the project, delimiting the amount of resources that could be used during the planning, design and execution of the

project. These will have direct consequences on the time and the quality too, although the completion time is usually fixed.

Figure 2: Iron triangle

A project must be expertly managed to deliver on-time, on-budget results, dealing with the integration that the organizations need. For that, a project manager is needed. The **Project Management** is about *making something complex happen* (Martin, 2000), and ensures that the projects goals are reached by applying their methods. *"Project management is the application of knowledge, skills, tools and techniques to project activities to meet the project requirements"* (PMBOK, 2013). It concentrates on the planning, management and promotion of single projects applying systematic management practices and methods, which are common success factors in all the projects. The project management brings a unique focus shaped by the goals, resources and schedule of each project. For that, it is necessary to ensure that the project's goals and objectives are defined. The tools, knowledge, skills, methods and behavior of project management are general enough to apply them in various types of projects, although as mentioned before, each project has its uniqueness.

The project management has recurring elements and main processes fall into five groups. Initiating, planning, executing, monitoring, controlling and closing are the main steps during a project and each one is usually finished and revised before going ahead. To know how to deal with each of them the knowledge areas classified by PMI are: Integration, cost, human resources, stakeholder management, scope, quality, communication, time, procurement and risk management. (PMBOK, 2013).

To achieve all these, various standards have emerged. Standards are documents that are established by consensus and approved by a recognized body, and are provided for

common and repeat use, rules, guidelines or characteristics for activities or their results, aimed to achieve the optimum degree of accomplishment in a given context. At the end, project management is a critical competence that has a positive influence on organization results and society.

But as experience has shown, it is not enough with all those standards and the theory based knowledge taught to guarantee that projects do not fail any more.

2.1.2. Simulation

Mapping through the countless definitions of simulation, the most significant ones related to the topic that is being researched had been selected. The next overview helps to understand the concept and the aim of using this tool for educational purposes.

Def. 1: *"The imitation of the operation of a real-world process of system, over time"*. (Banks;Carson;Nelson;& Nicol, 2000).
Def. 2: *"The construction and manipulation of an 'operating' model, a physical or symbolic representation of all or some aspects of a social or psychological process"*. (Dawson, 1962).
Def. 3: "*Imitating a certain phenomenon by using another device"*. (Ohnari, 1998).
Def. 4: *"Simulation replicates aspects of real environments though models, which can be used for extrapolating theory, validating hypotheses, or revealing emergent behavior"*. (Washington, 2008).
Def. 5: "*Using a model to develop conclusion providing insight on the behavior of real-world elements being studied"*. (McHaney, 2009).
Def. 6: "*Any procedure that is meant to imitate a real life system*". (Mahboubian, 2010).

So making an analysis of the definitions above, can be seen that simulation is mainly defined as a way of modelling and acquiring new knowledge by studying a process over time, which can be used as a teaching tool that makes students understand the behavior and evolution of a project. This tool makes accelerate the learning process and contributes to improve the quality of the work that is being carried out.
Simulation needs to generate an artificial history of a system, a simulation model. The model takes form of a set of assumptions concerning the operations of the system.

These assumptions can be expressed in mathematical, logical and symbolic relationships between entities and objects of interest of the system.

So, modelling is one of the ways to solve problems that appear in the real world. In many cases it is hard to afford finding the right solution by experimenting with real objects; building, destroying, or making changes may be too expensive, dangerous or impossible. That is why is built a model out from a real system, only keeping the important things from the real system. “Modelling is about finding the way from the problem to its solution through a risk-free world where it is allowed to make mistakes, undo things, go back in time, and start all over again.” (Borshchev, 2013).

2.1.3. Use of simulation to support experiential learning

To achieve the project’s target, the project manager needs to deal with two main challenges. The relevant knowledge is quite large and complex and general issues are necessary to carry out the projects properly. In addition to the theory based knowledge, the project manager needs to know how to apply this knowledge in complex operating environments.

It is known that individuals learn through a process of conceptualization (where the person will acquire the theory and will build their mental models) and through experimentation (where the conceptualized knowledge will be applied). “*Tell me, and I will forget. Show me, and I may remember. Involve me, and I will understand”* (Confucius, 500BC). For instance, the conceptualization is linked to the traditional classroom methods such as using textbooks and attending lectures, whereas simulation will approach the project manager to those complex environments and will help to learn how to deal with an interactive process over time.

Project Management simulations are used to support making decisions in real projects and to deal with the what-if analysis and find the factors that are going to be relevant during the project. In other cases, it is also used as training simulation for the project managers it self’s and for supporting education activities. The simulation of the process, including the whole life cycle of a project, will reduce organizational risks; facilitate team structure on processes, roles and expectations; and help leaders gain the skills to achieve an exceptional performance from their workers.

Simulation has been already implemented in teaching activities with the purpose of improving the students competencies by putting into practice realistic cases and making them to face and solve the problems. It is proved that simulation-based training is superior to problem-based learning for the acquisition of critical overview and management skills (McCreery, 2003). The simulation exercise improves not only participant knowledge levels, but also the ability of participants to apply that knowledge. Practical and direct problem solving is different from the theory and makes students to make decisions under uncertainty, and face then their consequences. The experience of driving a project and taking it forward in their own or in groups making strategic decisions to achieve the target is a powerful learning device.

Nowadays several issues had been arising for only using traditional methods in management education. According to several community members the next ones are the most significant problems:

- The existence of gaps between textbook learning and the operational circumstances that are hold in real life. (Freeman & Dumas , 1989).
- Gaps between untranslated knowledge and uninformed experimentation. (Larreche, 1987).
- Mismatches between conventional knowledge on management functions, tools and systems on the one hand, and actual managerial behavior on the other. (Kotter, 1982).
- Gaps between left and right-brain activities, and imbalance in traditional school teaching methods. (November, 1993).

That’s way the potential that simulation has can be used to address this gaps. Self-discovery and learning by doing, by struggling, by evaluating good and bad actions increases the efficiency of the learning environment. So, the clear advantages of software based simulation include: (Martin, 2000)

- Tools are sufficiently general to be transferable between different types of project.
- The students are released from tedious calculations; at any time the students can view the network and critical path, activity floats, Gantt chart, overall cost and duration, presented by the computer.

- The interfaces are attractive; they have standard controls and are easy to use.
- The software allows a controlled amount of random events and responses to decisions, and they have the absolute control of the time.
- The computers can record the events, decisions taken and other information to support debriefing and other analysis. Once the model is built up you can modified it and search for different solutions and make also a sensitivity analysis and optimizations.
- Helps students to understand the potential impact of various decisions on the network as changes happen.

2.2. Characteristics and managerial challenges in project business

During this sub-chapter the main characteristics of project management are going to be analyzed, focusing mainly on the attributes that make a project complex. Figuring out the key points of the successful project management will help to build up the adequate simulation model to later implement it for teaching these attributes to the future project managers in a risk-free world. This method will guarantee a better understanding of the complex environment and a clear and faster assimilation of the main concepts.

2.2.1. Managerial challenges of a project network

Here there, project business research field is emerging adopting a business-centric view to the management of projects, firms, and networks of projects and firms. The term “project-based firm” is used to refer to both to firms that conduct part of their operation using projects and to firms that organize most of their internal and external activities in projects. A project itself means as above mentioned, a delivery system of a firm´s internal development or external business activities.

Project business includes activities positioned within the boundaries of projects and firms as well as aspects of collaboration within whole networks of multiple firms. The Table 1 represents the project business frameworks. This highlights that projects and firms are both independent entities and interdependent networked organizations. All these firms and other organizations are relevant stakeholders interacting with projects and project-based firms in the marketplace. (Artto;Davies;Kujala;& Prencipe, 2011).

	Stakeholders	
	One firm	**Many firms**
One project	1. Management of a project	3. Management of a project network
Many projects	2. Management of a project-based firm	4. Management of a business network

Table 1: Framework of project business

During this research the factors related to the organization and management of project network are going to be analyzed. The projects could be addressed across multiple participating firms and other actors each of which have their own objectives, interests and expectations from the project. That is why the project business should address the managerial challenges taking into account the specific complex organizational context in each management area. In the Table 2 are presented the main attributes the management that a **project network** should deal with. (Artto;Davies;Kujala;& Prencipe, 2011).

	Unit of analysis	The managerial challenge is…	Issues from the analysis that characterize the complex organizational context
Management of a project network	A project as a multi-firm network	… to manage a project as a multi-firm enterprise thought managing multiple firms participating in the project, by creating a contractual or an organizational arrangement that enhances goal alignment and coordination across multiple firms.	Asymmetry of participating firm´s objectives, diverse interests and identities, dynamism in the network, coordination of actors from different cultural and institutional environments.

Table 2: The main managerial challenges in management of a project network

The management of the project network is emphasized by the fact that the project network is a temporary endeavor which includes several distinctive phases each of which has a continuously changing constellation of actors in ever-changing roles.

(Dubois & Gadde, 2000) (Morris, 1983). These implies several parameters to work with and interlink, which sums up adding a high complexity level to the project itself. So as, first the attributes related to complexity that most commonly can be found in this kind of business project are going to be analyzed.

2.2.2. Project complexity

Now a days complex projects demand an exceptional level of management and the application of conventional systems developed for ordinary projects have been found to be inappropriate for these projects. So research, as shown above, has proved that this is one of the main reasons why projects still continue to fail.

There are different point of views about which is the definition of a complex project. A project would only be complex when uncertainties play a role, if not, the project at most would be complicated. (Whitty & Maylor, 2009). But even understanding the complexity does not mean that the control of the complexity is assumed, that's why understanding project complexity in order to better manage projects is not automatically focused on reducing project complexity. (Bosch-Rekveldt, M., et al., 2010).

So as to identify the elements that contribute to project complexity, some definitions have been investigated:

Def. 1: *"Consisting of many varied interrelated parts"*. (Cambridge dicctionaries, 2015)
Def. 2: *"Complicated, involved intricate"*. (Cambridge dicctionaries, 2015)
Def. 3: *"Complexity refers to the study of complex systems, of there is no uniformly accepted definition because, well, they are complex"*. (Parwani, 2002).
Def. *4: "Complex projects are open, emergent and adaptive systems that are characterized by recursive and non-linear feedback loops"*. (Australian Goverment Departament of Defence, 2012).
Def. 5: *"Project complexity consists of many varied interrelated parts and can be operationalized in terms of differentiation and interdependency"*. (Baccarini, 1996)

In projects, complexity is mainly related to structural elements, dynamic elements and the interaction of these, broader than the technical or technological domain. Project

complexity is about many varied interrelated parts, to be operationalized in terms of differentiation and interdependency.

Although the specific path followed by the behavior of complex systems is chaotic, there are underlying patterns. Thus one of the main aims of complexity studies is to develop concepts, principles and tools that allow one to describe features common to varied complex systems. This later helps to develop a framework to grasp project complexity. (Bosch-Rekveldt, M., et al., 2010). So the competence to understand and proactively deal with these patterns is what distinguishes complex, executive project managers; and this is one of the strong points that they need to learn to deal with during their project management education.

2.2.3. Attributes related to complexity in project business

First of all, and so as to develop a set of premises within a framework in which project business can be build, the challenges/attributes related to organizing and managing a complex project network need to be identified. There is a main classification of projects according to whether the goals of the project (What?) are well defined or uncertain and whether the methods to achieve these goals (How?) are well defined or uncertain. (Bosch-Rekveldt;Jongkind;Mooi;Bakker;& Verbraeck, 2010). And these attributes are directly connected to a projects structural complexity, and uncertainty.

Structural complexity refers to two main challenges. First, a structure containing differentiated parts so that the greater the differentiation, the more complex organization is. And the second, the structural complexity that makes reference to the degree of operational interdependencies and interaction between the projects organizational elements.

The project complexity is often considered as being caused by **uncertainty.** This term in projects has been defined as “a context for risks as events having a negative impact on the project’s outcomes, or opportunities as events that have beneficial impact on project performance” (Perminova;Gustafsson;& Wikström, 2008). To get under these complexities, the key elements in managing uncertainty are reflective learning and sense making, flexible and rapid, decision-making in response to the particular characteristics of each situation (Perminova;Gustafsson;& Wikström, 2008).

A part from the challenges above mentioned, there are also two main dimensions to classify softer aspects of complexity in projects: (Brujin;de Jong;Korsten;& van Zanten, 1996)

- Technical complexity:
    - Technological uncertainty. Technology is defined as the transformation process which converts inputs into outputs and can have three main facets where the uncertainty can be present: operations, characteristics of materials and characteristics of knowledge. (Baccarini, 1996)
    - Dynamics
    - Uniqueness of the project. Usually each project has a specific set of operations designed to accomplish a singular goal.

- Social and organizational complexity:
    - Actors involved (multi-objectivity and multiplicity of stakeholders)
    - Risks
    - Consequences of the project in relation to its environment
    - The project team

Therefore, as shown in the social and organizational complexity classification, the actors involved have a big role as project´s goals are different from those of its stakeholder firms, and the project goals may be in conflict with stakeholder firm´s goals. This results mainly in the next challenges to deal with; firms with different objectives; diverse interests and identities; different cultural and institutional environments; projects with strong local orientation; higher risk; uncertainty. These, leads to network effects such as dependence on other actors, interest asymmetries, different identities, nonexistence of information, information asymmetry in the network, social and institutional risks and risk management procedures that do not fit into the network context. (Artto;Davies;Kujala;& Prencipe, 2011).

Since the above mentioned is an important source of complexity in projects, it is really important to know how to deal with all this factors and acquire the necessary knowledge to manage it and do not let these to make fail the project, as there are many more attributes related to the operations, interdependencies between activities and uniqueness in the project, that are harder to manage than these.

2.2.4. Managerial approaches related to complexity

After the identification of the main attributes related to complex projects, depending on which challenges the project has, an appropriate managerial approach needs to be selected. Nevertheless, there is stablished that by integration, that is, by coordination, communication and control project complexity can be interpreted and operationalized. (Baccarini, 1996).

Managing in challenging institutional environments. In huge projects, the social and organizational environment it is difficult to coordinate. Several actors are involved what leads to multi-objectivity between the actors and the several stakeholders. To deal with this matter, it is important to have dynamic collaborative and competitive relationships with the partners. It is also necessary to manage a wide socio-political environment and make a research on stakeholders and the stakeholder's network to interpret the challenging institutional environment. For that, it is crucial to have a permanent communication and to adapt to the projects particular environment. Local presence or the use of local partners also helps in the capability to adapt to local business environments.

Risk and its management in complex organizations and networks. In these environments it is appropriate to introduce appropriate governance structures and risk management schemes to deal with these situations. It is important to have a robust organizational strategic system to anticipate the risks and have properties to react to unexpected situations. Developing a plan to know how to manage risks in short and long term it's also suggested.

Learning capabilities in project-based organizations. Working in a huge project network with different background people makes understanding complicated in some situations. Knowledge sharing helps to achieve collective competences, and group abilities and working together towards a common goal/result provides the creation of a collective outcome. Understanding the outcome of the project and its composition based on the composition of each party's objective provides a better view of the networks achievement too. So inside project learning contributes to build the required capability within the network, improving the collective performance.

Business logic in project-based organizations. It is been researched projects using theories from business strategy and other related areas to explain their logic. By implementing the concept of a business model might introduce new business-centric paradigm in the management of single projects.

The approaches above mentioned (Artto;Davies;Kujala;& Prencipe, 2011), demonstrate that there is the need of achieving goal alignment between the owner and the contractor, so as to reduce the chance and benefit for opportunism by the owner or contractor. It is considered very important to choose the type and content of the contract between the parties (Turner & Simisters, 2001). Thereby, to achieve those targets it is necessary to emphasize on the relationships between the organizations in the projects network, where no actor alone has total control over the network. In fact, modular product and process structures further enables system integrators to rely on more unstable organizational structures in the form of a network of suppliers. (Artto;Davies;Kujala;& Prencipe, 2011).

2.3. Summary of the literature

The first research question of this thesis focuses on finding out how simulation supports management education and which are the advantages that this tool can provide to internalize the main characteristics of the project management.

Using the literature presented during the first sub-chapter here, first of all some basic terms have been defined to have a better view about the scope of the question. **Project business** has been defined for this thesis as**, "***the part of a business that relates directly or indirectly to projects and is nowadays really applied with the purpose of achieving objectives of a firm or several firms"* (Artto & Wikström, 2005). Project business itself is about using a project as a tool of achieving a goal, where a **project** makes reference to a temporary endeavor undertaken to create a unique product, service or result.

But projects now a days are complex interfaces that need to be guided through some predefined steps and taking into account several different parameters to guarantee the success. Here is where **project management** makes sense, applying these knowledge, skills, tools and techniques to project activities and meet the stakeholders' requirements.

The problems is that even various standards have been launched and implemented, the formation of these project managers is still poor comparing to the challenges in the real world. That is why a simulation model is being investigate so as to use it as a teaching tool because is known that individuals learn through a process of conceptualization.

Simulation has been defined in several ways during this chapter but one that better fits our purpose makes reference to it in this way: "*Using a model to develop conclusion providing insight on the behavior of real-world elements being studied"* (McHaney, 2009). So it is visible that **modeling** is about finding the way from the problem to its solution through a risk-free world where it is allowed to make mistakes, undo things, go back in time, and start all over again (Borshchev, 2013).

It is proved that simulation-based training is superior to problem-based learning for the acquisition of critical overview and management skills (McCreery, 2003). These is why the second research question is going to find out which are the key challenges that a model should gather so as to guarantee that the simulation provides the users the adequate knowledge and skills to deal with the real world complex projects.

So as to find the adequate literature for the next research question, the characteristics and managerial challenges in project business have been analyzed in order to figure out the key points of the successful project management. This, as mentioned above, will help to build up the adequate simulation model.

In **the management of the project network** (many firms in one project) is emphasized that the project network is a temporary endeavor which includes several distinctive phases each of which has a continuously changing constellation of actors in every-changing roles. It is enhanced that goal alignment and coordination across multiple firms leads to better results, dealing with the complexity that those characteristics add to the project.

When talking about **complexity in projects** environment a definition that fits with the context of study and after researching some others says *"Project complexity consists of many varied interrelated parts and can be operationalized in terms of differentiation and interdependency"* (Baccarini, 1996). As complexity has been shown to be one of

the main reasons of projects failing, the main attributes related to it and project management had been studied to provide a better outcome from the project by searching for the underliying patterns behind the chaotic behavior of the systems.

The main challenges related to complexity can be differenciated in two main groups. The ones related to the **structural complexity**, that could be because of the differentiated partes in the structure or because of the degree of operational interdependencies. The others are related to **uncertainties**, that can be attenuated by reflective learning of decision making. Usually in a project network, technology, social and organizational complexities are the most relevant and the ones that should be controlled by applicating the convenient managerial approaches. Managing in challenging institutional environments, risk and its management in complex organizations and networks, learning capabilities in project-based organizations and business logic in project-based organizations are the four managerial challenges that proceed from the project business framework.

3. Design of the simulation model

3.1. Characteristics of a simulation model in project business

To study the behavior of a system, a simulation requires a model to generate an artificial history from that real process. The model contains the observations, set of assumptions, and inferences concerning the operating characteristics of the real system. These can be expressed with mathematical, logical, and symbolic relationships between the entities and objects of interest of the real system. A simulation model consist of five basic elements: the initial conditions, the time structure, the outcome determinations, iterations and variations. It is also necessary to decide the boundaries between the system and its environment to obtain the needed results.

In the context of a large business project, where uncertainty and complexity are closely related to the tasks, a simulation model is going to be implemented so as to learn how to deal with these attributes and acquire the necessary knowledge to manage the challenges of nowadays. The thing is that when a project process is approached, two main levels are found, the one referring to the organization implementing the project, and another level where the tasks are implemented.

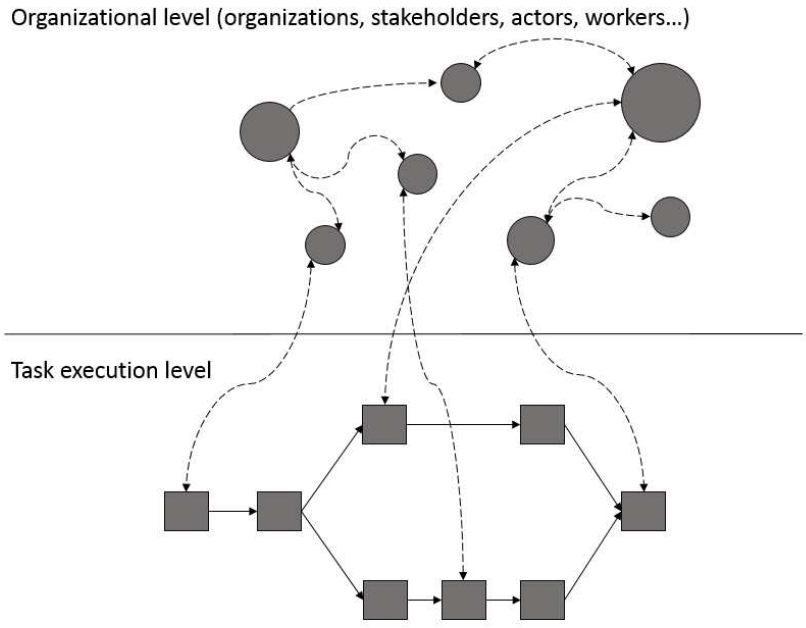


Figure 3: Project network two main levels

As shown in the figure above, the organizational part deals with the coordination of the actors involved, takes decisions, and it's closely connected to the task executions level too, as it's in charge of it. Basically making reference to the literature that has been studied, it's the part related to the social and organizational complexities. Manages multiple firms, several actors from different environments, different objectives, and all the relations, connections and communications between them.

In the case of the task execution level, there is where the challenges related to the organizational part and the tasks are located, and also the task implementations itself. The ones referring to the task implementation itself are mainly the ones related to uncertainties, and complexities related to structural and operational interdependencies.

3.1.1. Challenges in task implementation level

In project management, a **schedule** is a time management tool that lists activities, and deliverables, usually with start and finish dates limited by the stakeholders. Those items are often estimated in terms of resource allocation, budget and duration, linked by dependencies and scheduled events.

During the execution, projects may be subject to considerable uncertainty during their task durations or other external facts affecting the project, which may lead to numerous schedule disruptions. Recent research efforts have focused on the generation of robust project baseline schedules that are protected against possible disruptions that may occur during schedule execution. To obtain this robustness, **time buffers** are inserted in the necessary tasks through the projects schedule in order to maximize the schedule stability. The project management should decide whether to implement them, but usually they are common in those projects where a heavy weight is given to projects timely completion or when robustness really matters. (Van de Vonder;Demeulemeester;Herroelen;& Leus, 2005).

In addition, all the projects have as before mentioned, a predetermined **budget** fixed by the stakeholders, and that is another reason why it is so important to control all the parameters that can affect to the final cost of the project. Every change in the duration

of the project has a direct effect on the total budget. Even the quality, the use of human resources or the buffer allocation have a direct repercussion on the total cost.

When talking about **quality**, it is defined as a measure of excellence or a state of being free from defects, deficiencies and significant variations. It is brought about by strict and consistent commitment to certain standards that achieve uniformity of a task in order to satisfy specific stakeholders requirements. (Business Dictonary, 2015).

The next examples collect some challenges from both levels that refer to those attributes above mentioned.

Uncertainties, time buffers	The Project Manager can assign time buffers to the project to protect the critical path and especially the tasks that are difficult to reschedule. In case the work is delayed, a cost should be added for the rescheduling.
Incentives	The actors earn money by completing tasks based on the work they have been able to accomplish, depending on the contract model. They also earn more money if the project is done under budget, but if the actor is late, there is a penalty associated with that.
Quality in tasks	By reducing the resources spend for a task, quality would be lower but the execution of the task is faster.
	Within the project, there are three or four actors that are assigned to work on the tasks and each actor is assigned between one and three tasks. These are assigned with specific skills, higher skill levels lead to faster and higher quality work.
	The quality of an accomplished task related to the overall quality of a project, and lower quality in one task may lead to lower quality is subsequent tasks (determined by quality links between tasks).
	The skill of the project manager determines whether he can detect low quality work. This can lead to rework the low quality work.
Heterogeneity of actors	Multiple firms participating in the project/different companies; with different objectives/goals, diverse interest and identities, dynamism in the network, coordinate different cultural and institutional environments.

Table 3: Example of characteristics in complex project context

3.2. Selection of a simulation software

In this case, the software **Anylogic 7** is used to build and simulate the model of the real system mentioned above. Anylogic is a multimethod simulation modeling tool developed by The AnyLogic Company, which supports discrete event, agent based, and system dynamics simulation. It has a graphical interface, tools, and library objects that allows modeling different systems and also allows self-programming any specific need through Java language.

In the beginning of the 1990s there was a big interest in the mathematical approach to modeling and simulation of parallel processes. The Distributed Computer Network (DCN) research group at Saint Petersburg Technical University developed such software system for the analysis of program precision; the new tool was named COVERS (Concurrent Verification and Simulation), and allowed graphical modeling notation for system structure and behavior.

In 1998 the success of this research inspired the DCN laboratory to organize a company with a mission to develop a future simulation software. The emphasis in the development was placed on applied methods: simulation, performance analysis, behavior of stochastic systems, optimization and visualization. The new software was released in 2000 and was based on the latest advantages of information technologies: an object-oriented approach, elements of the UML standard, the use of Java, a modern GUI, etc. The tool was named AnyLogic, because it supported all three well-known modeling approaches: System dynamics, discrete event simulation, and agent-based modeling. The first version of AnyLogic was AnyLogic 4, because the numbering continues the numbering of COVERS 3.0.

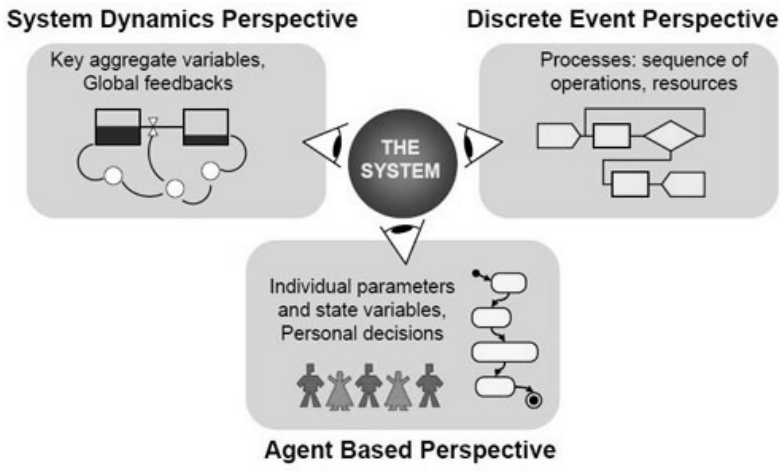


Figure 4: Three business simulation approaches

In 2003, a big step was taken by the company when AnyLogic 5 was released. In this case a new view was given and it was focused on business simulation in the following domains: Market and Competition, Healthcare, Manufacturing, Supply Chain, Logistics, Retail, Business Processes, Social and Ecosystem Dynamics, Defense, Project and Asset Management, IT Infrastructure, Pedestrian Dynamics and Traffic simulation, Aerospace and Photovoltaics.

AnyLogic 7, the last released edition, and the one used for developing the models presented in the thesis (the educational version by the way), was released in 2014. Being the biggest release for 7 years, it featured many significant updates aimed at simplifying model building, including enhanced support for multimethod modeling, decreased need for coding, renewed libraries, and other usability improvements. AnyLogic 7.1, also released in 2014, included the new GIS implementation in the software.

The AnyLogic Company now a day's is a leading provider of dynamic simulation tools, technologies and consulting services for business applications. It designs, develops and markets AnyLogic - the first and only tool that brings together System Dynamics, Process-centric (Discrete Event), and Agent Based methods within one modeling language and one model development environment. The language of AnyLogic has unmatched flexibility and enables the modeler to capture the complexity and heterogeneity of business, economy and social systems at any desirable level of details to gain deeper insight into interdependent processes going on inside and around the organization. These is why the software has become a corporate standard for simulation in many global companies. (AnyLogic, 2015) (Borshchev, 2013).

The main reason for choosing this software for developing the models has been because it presents the two main perspectives that can be used in approaching a project process system to a simulation model. The agent based feature gives the opportunity to implement the organizational level; facilitating different relations between the agents that could enable to visualize the impact of the conflict in goals, values and cultural norms in the project team. The discrete event approach enables to implement most of the characteristics related to the task execution level; buffers, salaries, paychecks, workers, etc., but not the ones referred to those organizational complexities using the agent based approach.

3.3. Scope of the model and learning goals

The scope of the models is limited to develop them by the discrete event approach implementing the main characteristics related the task implementation level so as buffers, salaries, paychecks, workers, etc., but not anything referred to those organizational complexities using the agent based approach. So underline that the model that is going to be design is not going to simulate the entire project network that will be mentioned during the literature, but will only be the star point for in a future implement a model that can be used in complex project processes.

The aim of designing this simulation model is to build it with such characteristics, that later could be used as a learning tool in project management education environment. It is being implemented so as the students can purchase the most attributes related with project management and to understand how and why something happens in the real life by using simulation and interacting themselves with the system. The main project management objectives that will be transmitted are schedule, budget, buffer allocation, task structure organization and interactions, use of human resources and quality management. So the real factors affecting real projects will be studied and individual areas of the project analyzed to see how the changes in each one affect to the whole project realization and final output.

With the simulation, one of the aims is to clarify the **project planning** and enhance the significance of rigorous planning in order to control the tasks and the interactions and interdependencies between them. The characteristics affecting the project schedule, so as the project critical path, the total **budget**, the **quality** of the work that is being realized, and the distribution of the **buffers**, are going to be analyzed so that the user can visualize how changes on these parameters affect the final duration. A good approach will be to know which tasks are more critical and can cause delays, so that with a correct allocation of the buffers, or redistributing the human resources, the total duration and cost of the overall project can be fulfilled according to the needs of the stakeholders. The above mentioned is really connected to understand the interdependencies between the tasks too, because managing those is one of the most complex challenge in project management.

It will be also possible to vary the amount of people working in each task, the number or **human resources**, workers. This can be useful to plan how to act if there is any kind

of complication or delay in one task, giving the possibility to still reach the requested duration of the project by adding more resources in the following tasks, so as to recover the lost time. But changing this parameter will also affect the total cost of the project as adding more human resources implies to dedicate a bigger part of the budget to it. By playing with those scenarios the students will be able to realize how those parameters changes imply significant variations in the final output values.

At the end, the main goal is to learn to **evaluate the results** obtained from the simulation, analyzing them according to the objectives, taking decisions and acting consequently.

3.4. Simulation model

The creation of the computational model consists on taking the relevant system components such as variables and specifications, and write them as equations and rules for the processes specifying how the values of variables change with time, how the next stage of the system is reached from the current state. That is why a dynamic model is used, considering the passage of time, but the change of the states of the variables is still discrete.

To represent the behavior of the system, the simulation type is mathematical because the logical and quantitative relationships of the system are expressed in mathematical formulas. As the relations are complex, this leads to have a numerical simulation, which deals with the behavior of systems instead of working with the optimal solutions.

With the AnyLogic software, the **Discrete Event** approach is going to be implemented, as the systems consists of various consequence of operations, related to resources, time, and other parameters that can be easily modelled using this perspective. Each operations is modeled by its start event and end event, and no changes can take place in the model in between any two discrete events. It’s a way of approximating the reality by instant changes at discrete time moments, which in this case will make reference to the activities/tasks.

The model implemented is stochastic as in some input variables uses distribution functions, in particular in the task duration times. This results in random outputs, so

results only can be considered as estimates of the true characteristics of the model. The stochastic approach relies on the idea that probabilistic components have distributions that can be sampled to obtain values used as inputs for the computations in the model, using random number generators. That is why to determine the pattern of outcomes the simulation must be repeated many times, for example using a Monte Carlo simulating method.

This method consists on a numerical simulation technique of approximating solutions for phenomena through computer algorithms employing the generation of random numbers. It is used to make predictions about the stochastic processes, or phenomena having some random component. Generally involves simple algorithms for computing numerical probabilities in which the objective is to understand the working of a real life system by imitating it as well as possible on a computer.

In a pedagogical context, the simulation, the “virtual experiment” can be run varying experimental conditions to obtain different results and see how changes affect to the project outputs.

The model will consists on a simple project with 10 interrelated tasks, presented in an activity node diagram (PERT), were there is uncertainty related to the duration and work required of each task (activities). The number inside each activity box refers to the mean duration of the task. Each of the models presented below has its own characteristics.

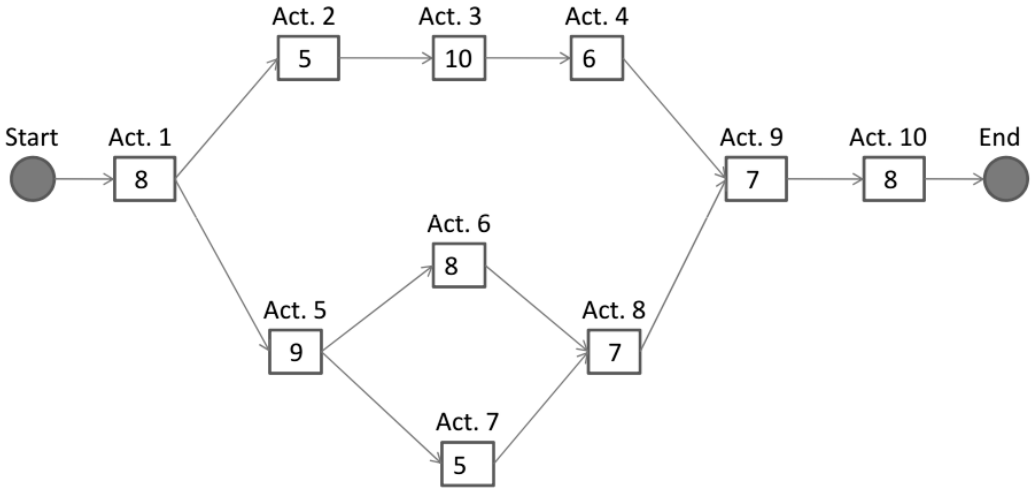


Figure 5: Basic layout of the simulation with the durations of the activities

3.5. Model 1: Budget allocation

This first model is the one used during the Project Management Simulation Workshop, in May 2015, in the University of Oulu. The system that has been modeled is a simple project network with 10 tasks that are interconnected and linked some in parallel and others in series, with only one worker per task.

The durations of the tasks are implemented by a beta distribution. Such distribution is used commonly to model events which are supposed to take place within an interval defined by a minimum and maximum value, as is a continuous distribution that has both upper and lower finite bounds. For this reason, the beta distribution is used extensively in PERT, critical path method (CPM), Joint Cost Schedule Modeling (JCSM) and other project management/control systems to describe the time to completion and the cost of a task. In this case, it is used to obtain a random value of the duration time of the tasks. Each task has its predetermined mean duration, and later a beta distribution is used to obtain the random durations according to the next parameters:

$$\alpha = 2$$

$$\beta = 5$$

$$\text{Lower boundary} = \text{mean} - 1$$

$$\text{Upper boundary} = \text{mean} * 2$$

As mentioned before, there is only one worker per task so as to visualize better how the changes in the main parameters affect the final outcome. The model principally calculates the time it takes to complete the project, allows changing the buffers, and calculates the final paycheck having into account the random durations of each task and the buffers allocation.

When talking about the buffer's allocation, they have been implemented following the next logic in order to calculate the final value of the workers' paycheck.

Mean = m
Duration = d
Buffer = b
Salary = s
Paycheck = pc

"if d ≤ m:
*pc = pc + (d+b)*s*
elif d > m and (b+m) ≥ d:
*pc = pc + (m+b)*s*
elif d > m and (b+m) < d:
*pc = pc + (m+b)*s + (d-b-m)*s*2"*

This way they can be considered all the possible options of duration and buffer relations and the consequent paycheck calculation equation can be applied. In the case the duration exceeds the buffers and the mean, the extra times cost is considered to be the double of the salary. And in case a buffer it is not used or at least not completely, it's going to be paid though.

With this model, a part from trying different scenarios and watching how changes affect to the outputs, it's also possible to run a couple of interesting experiments. The first, an optimization, where in order to minimize the final cost of the whole project, fixing the durations to the means, running the experiment obtains the optimal buffer allocation. The second, running the Monte Carlo method, where in order obtain the distribution of values of the total cost, the experiment runs through the duration values of the distributions of the tasks, while the buffers are static. This provides a way of finding the optimal solution for the buffer allocation, which will reduce the final cost of the project.

The model is described in a more detailed/technical way in the Appendix A.

3.6. Model 2: Adding more resources and quality

The basic of this model is the one described above but developed more deeply adding some more complex attributes that cover better than the one before the project network.

In this case, although it's still a general example of project network, it has been modeled using resources that in a real system could make reference to the construction of a house. The aim has been to implement different human resources that can be grouped according to the characteristics of each one and later used according the particular necessities of each task. Doing these the paycheck calculation becomes harder as its necessary to identify who is working in each task, how long, and link it to that worker's salary type.

During the entire project network the presence of the project management has also been implemented, so as later can be used to interact with the tasks. A quality variable for each task has been introduced too, that calculates the quality at the end of each task according to the abilities of the workers that have been working on it.

In this case the experiment that is worth running is trying to make different scenarios where the amount of workers per task varies and see how this affects to the cost and duration outputs, and also to the final quality value that moves between 0, no quality, and 1, perfect quality.

The model is described in a more detailed/technical way in the Appendix B.

3.7. Validation of the model

3.7.1. Description of the Workshop

During this thesis, a couple of simulation models have been developed for the purpose of project management education. The models were used as a practical exercise in a Project Management Simulation workshop so as to introduce the advantages of simulation-based training. Also the validity of the models was tested empirically during the workshop through the exercise and with the participants' feedback at the end.

This thesis was carried out during the spring 2015 in the University of Oulu, and the specific context in which the exercise was conducted was the Project Management Simulation Workshop in May. The workshop was arranged by the Department of Industrial Engineering and Management and was given in English. The structure of the workshop was the next one:

- Introduction to simulation. (theory, 2 hours)
- Hands on exercise building simulation model with AnyLogic. (practice, 1 hour)
- Simulation as an educational tool in Project Business. (theory, 0,5 hours)
- Building of the project network simulation Model 1. Study the model 2. (practice, 2 hours)
- Discussion about simulation in Project Business. (0,5 hours)

So as to the students be prepared for the theory and exercise that was going to be done, some previous lectures and a video about AnyLogic simulation were recommended. During the workshop, the main contents presented in the theory part were the next ones. In the introduction to the simulation, the terms simulation and simulation model were defined in this context and its main characteristics were explained. An introduction to the system dynamics, discrete event simulation, and agent-based modeling was given too, particularly focusing in the characteristics of the last one, as it's the most flexible method to model systems related to Project Management and the interactions that presents. Later on, the research theory of this thesis was introduced focusing mainly in the use of simulation as an educational tool for Project Management and which were the attributes related to complexity in this environment.

In terms of practice, after the first theory part, a slight introduction to the use of the software AnyLogic was done, first showing some examples of which things can be

simulated using the agent based method, and later building an agent-based model of consumer market, to help understand how a product enters the market and how to implement it by using the software's tools.

After the presentation of the thesis, the budget allocation optimization model was guided to the students so they could build it. First the objectives of the simulation model were explained, which basically are the next ones:

Initial problem: The durations of each task are uncertain and depend on various external factors.

The model will help to:

- Allocate properly the buffers
- Evaluate and understand their importance
- Understand how uncertainties in task durations affect the outcomes
- Realize how total cost and duration of the project varies
- Evaluate the results obtained through the simulation

After that, step by step how to build the Model 1 was explained. It was differentiated in four parts. First building the basic lay out and implementing it without any uncertainties and with only one worker per task. This way, the students could see how a project and its task could be implemented with a discrete event approach and how the cost was calculated too. Later, uncertainties were introduced to see how the final length and total cost varies with the beta distributions in the task durations values. When the buffers theory was explained and the option of allocating the buffers was built, with this new attribute, several different allocations where tried and the results were evaluated seen how this parameter and the uncertainties affect in the final outcome values. Next, and as the level of coding and of knowledge using the software was becoming higher, instead of building it themselves, some other prebuilt characteristics and options of the software were shown. How to, by an optimization method, allocate properly the buffers in the different task having into account the uncertainties and having as an objective to minimize the total cost of the project. To finish with the practical part, based on the same model, a more complex example was shown, Model 2, where there were 5 different agents, each one with its own resource pool. So there was more than one resource per task, which could belong to the same or different resource pool, what

implied that they could have different parameters. Some quality parameters were also introduced and a more complex developed structure was shown.

3.7.2. Results of the Workshop

A total of 5 students participated in the exercise of building the proposed model. The feedback data has been obtained through a questionnaire attached in the Appendix C. First of all, questions about the participants' background knowledge were done. Two of the participants were familiar to the theory explained about simulation and project, one was quite familiar to it and the other two had no contact with these themes before joining the workshop. All of them but one has not used AnyLogic before the exercise. Even they received some material to take a look before the workshop, from the observation through the exercise could be said that the majority of the students were not prepared enough for it.

The form also attached questions concerning the exercise built in the workshop and the specific model developed. All of the participants feel the simulation exercise was beneficial for them. Their statements related to this were the next; two of them made reference to have get new knowledge from it, "*Yes, it was beneficial because now I'm familiar with new simulation software's and the whole idea*". A couple said that they get the enough insights now to utilize the software in the future for their own research and that they feel it will be useful for them in the future. The last participant mentioned "*Yes, I think building and running the exercises is the best way you can learn a software. As you said: if you involve me, I will understand*". All of them agreed that putting the theory into practice helped them to clarify the themes presented in the theory part, "*Yes, Running several examples of different simulation methods was helpful. Because in this way the difference between the discussed paradigms becomes clear*". Others also mentioned the fact of putting the "*complex*" model into practice made it easier to understand, and that "*knowing how the process will function facilitates the decision making and not making that many mistakes*". They agree that the provided example of the project network tasks was useful, even one of the participants said that he had good previous experience with the logic and that he did not get any new theory knowledge from the models, but that learning the software's logic was interesting as well.

Responders were also asked to say whatever they consider the simulation was a proper tool as an educational tool comparing to the traditional methods and if it helped to achieve the knowledge's easier. The students answered as for them the simulation based learning had the next advantages:

- Comparing with the conventional way of education, this makes concepts easier to understand. Provides a better understanding of the system.
- It visualizes the problem and gives the opportunity to test different scenarios by a single click.
- Makes easier the failure recognition and also applying the optimizations to the system.

When asking about the AnyLogic software itself, and if they found it easy and intuitive it to use, they remarked that "*AnyLogic has special features that makes it an outstanding software between the simulation packages*", and that "*can be really helpful in academic circles, as after working with it sometime anybody can understand most of the logic and use it*". Another student also pointed out the need of more practicing to get the basic right on modelling and know how to apply it in other kind of systems.

The last question of the form made reference to how they think the exercise could be improved and what should be added to it so as to get a better insight of project management and the usage of simulation for its education. Here majority of students emphasized the fact that they would have liked to see how the software can be used in different scenarios and in examples from different industries, including agent based modelling. "*I would have added time and made participants to present their own proposals and solve problems, or I would have defined different scenarios to make student learn more about it*". Another one also would like to take more lessons about AnyLogic to get a better understanding of the software. More specifically speaking about the model used, "*running different scenarios to reduce the cost and time of the project propose would have been useful to get a better view of the system behavior*".

4. Discussion and conclusions

In this final chapter, based on the conclusions from the previous ones, a conclusion about the designed simulation models reflected to the researched literature will be given and also the answer to the research questions. Later, a critical evaluation of the research and some potential future studies will be suggested.

This research as mentioned in the introduction has been done to find out either if simulation could be a good tool to teach project management skills and which should be the attributes that a simulation model should include in order to succeed and provide the students with the necessary knowledge. For that a construction research has been used, which makes reference to a procedure for producing innovative constructions, intended to solve problems faced the real world and to make a contribution to the theory of the discipline in which is applied (Lukka, 2003).

It is proved that simulation-based training is superior to problem-based learning for the acquisition of critical overview and management skills (McCreery, 2003). With this assuption the research has leaded to find out that interacting directly with the system makes students get the knowledge faster. Thereby may result in using simulation models as a tool to address the gaps that nowadays are arising in the project management sector due to the rising complexity of the projects.

While designing the models, those shoul basically include attributes related to the two project process main levels, the one related to the organization implementing the project (social and organizational complexities), and another level where the tasks are implemented (interdependency and uncertainty complexities).

With the AnyLogic simulation tool, a couple of models have been implemented with the discrete model approach where attributes related to the operational level such as buffers allocation, structure management, resources allocation, quality management, budget management, etc. have been included. Later these models have been used in a workshop and validated by the students they participate by a final feedback form. Overall, the exercise had a positive echo as the majority of the students though the model was a

good approach to project management process and that the AnyLogic simulation software used during the workshop was fitting properly as a learning tool.

In conclusion, according to the result obtained through the survey, the simulation as a learning tool motivates the students and gives better and faster learning results than traditional methods. Despite the models designed should have some changes and should focus more in task level, in the future should be developed further with an agent based approach, to include all the attributes related to those social and organizational complexities to be more complete and more near to the real world project processes.

A future research potential seems to be developing a more complex simulation model, which includes more attributes using the agent based approach, to support that project business complex environment for educational needs.

References

A simulation engine for custom project management education2000*International Journal of Project Management* Vol. 18, 201-213

And then came Complex Project Managemet (revised)2009*International Journal of Project Management 27 (3)* 304-310

AnyLogic

ArttoWikström2005Waht is Porject Business?*International Journal of Project Management 23 (5)* 343-353

Assessing the value of a project management simulation traianing exercise2003*International Journal of Project management* Vol. 21, 233-242

Australian Goverment Departament of Defence. (2012). *Complex Project Manager Competency Standards.* International Centre for Complex Project Management (ICCPM).

Business Dictonary. (2015). Retrieved Abril 2015, from http://www.businessdictionary.com/definition/quality.html

*Business games: from business schools to business firms*1989Clevedon, EnglandMultilingual Matters Ltd

*Computer-based simulation research*2008Thousand Oaks, CASAGE Publications

Defining uncertainty in projects - a new perspective2008*Internatrional Journal of Project Management 26 (1)* 73-79

*Discrete-event system simulation. 3rd ed.*2000Prentice-Hall, New Jersey

Dubois, A., & Gadde, L.-E. (2000). Supply strategy and network effects: purchasing behaviour in the construction industry. *European Journal of Purchasing and Supply Managament 6* , 207-15.

2010Educational aspects of business simulation softwares

Grasping project complexity in large engineering projects: The TOE (Technical, Organizational and Enviroment) framework2010*International Journal of Project Management*

KasanenLukkaSiitonen1993The constructive research approach in management accounting research*Jorunal of Management Accounting Research 5* 243-264

Lukka. (2003). The Costructive Research Approach. Case study research in logistics. *Publications of the Turku School of Economics and Business Administration* , Series B, 1(2003), 83-101.

Major Projects: Decision-making and Management1996

Morris, P. (1983). Managing project interfaces: Key points for project success. In D. Cleland, & W. King, *Project manageent handbook* (pp. 3-36). New York: Van Nostrand.

On simulations in business education and research.1987*Journal of Business Research* 15:559-71

Parwani, R. R. (2002). *Complexity: an Introduction.* Singapore: National University of Singapore.

PMBOK2013*A guide to the Project Management Body of Knowledge, 5th ed.*Newtown Square, PennsylvaniaProject Management Institute, Inc.

*Project business*2011HelsinkiFinland

Project contract management and theory of organization2001*International Journal of Project Management* 457-64

Right- and left-brain marketing education1993*Journal of marketing education* 3-12

*Simulation Engineering*1998Tokyo, JapanOhmsha Ltd.

*Simulation in the social sciences. Simulation in social science: Readings*1962Prentice Hall, Englewood Cliffs, New Jersey

*The big book of simulation modelling*2013Anylogic North America

The concept of project complexity-a review 14 (4)1996*International Journal of Project Management* 201-204

2011The Project business: Analytical framework and research opportunitiesNew YorkOxford University Press

The use of buffers in project managemen: The trade-oof between stability and makespan2005*International journal of production economics* 227-240

Training for IS/IT project managers: a way forward.1997*International jurnal of Project Management* Vol. 15, No.5, 283-288

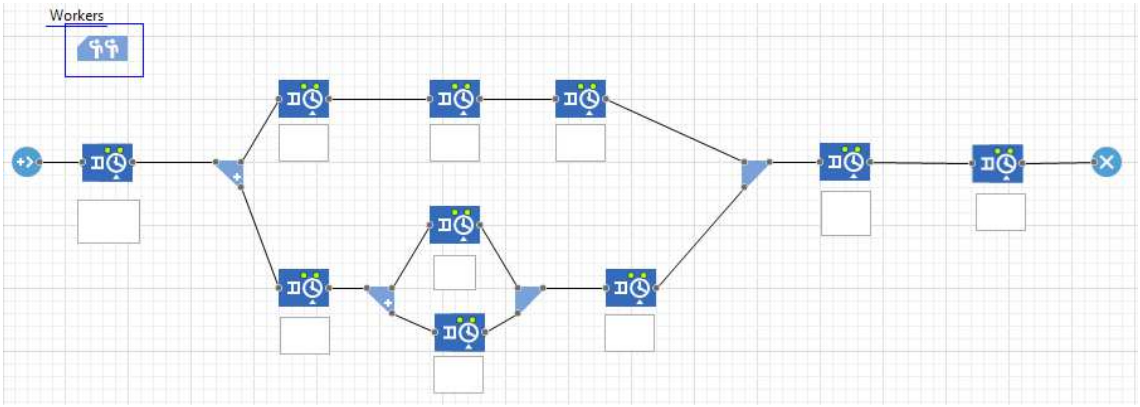
*Understanding computer simulation, 1st ed.*2009bookboon.com

What effective managers really do.1982*Harvard Business Review Nov-Dec* 156-67

Appendix A

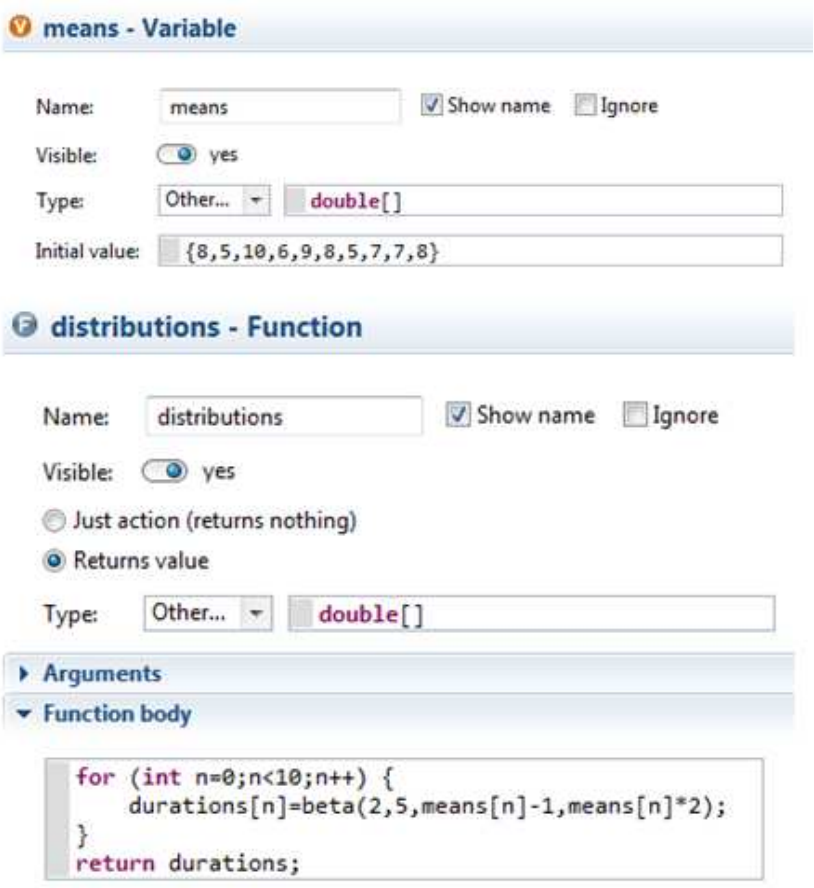
Model 1 – Budget allocation

This model consist on a project network with 10 tasks that are interconnected and linked some in parallel and others in series, with only one worker per task.



Appendix figure 1: Lay out and resource pool

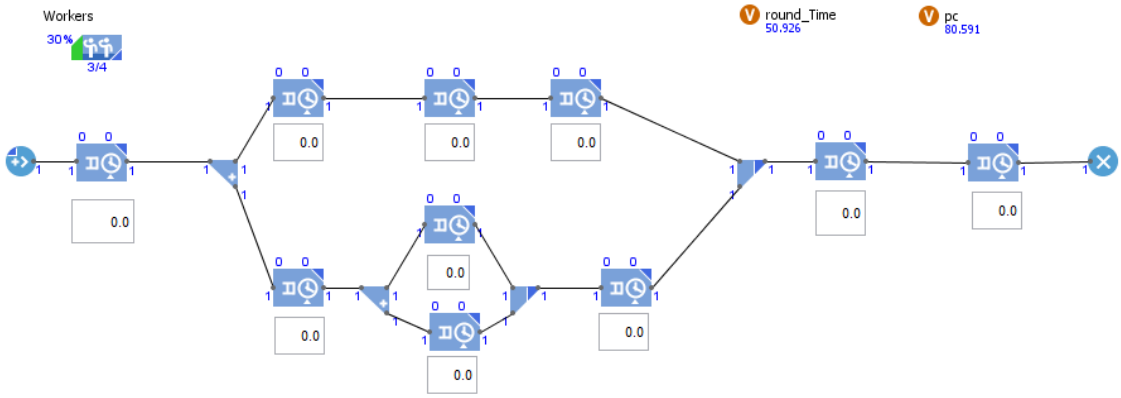
First the mean duration for each activity is defined and later the durations of the tasks are implemented by a beta distribution using a function shown in next figure.



Appendix figure 2: Properties in AnyLogic

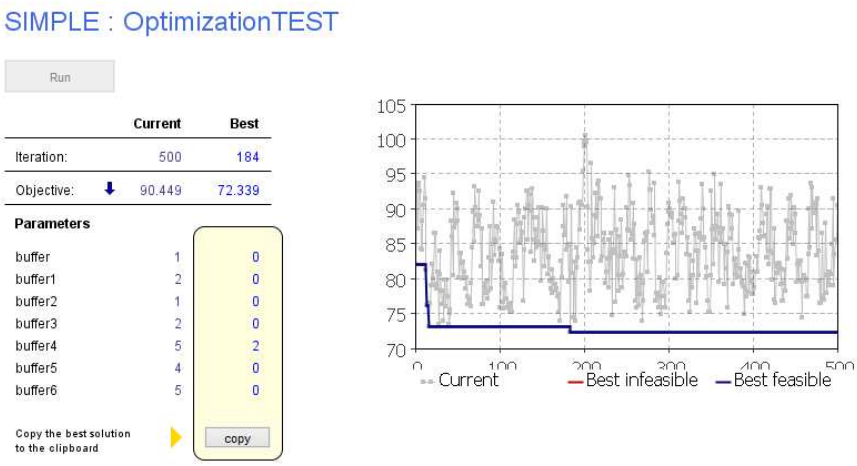
The buffers value can be changed directly from the boxes below each activity.

To calculate the final paycheck, several functions have been implemented in order to have an accurate result taking into account the different buffer and duration possible combinations.



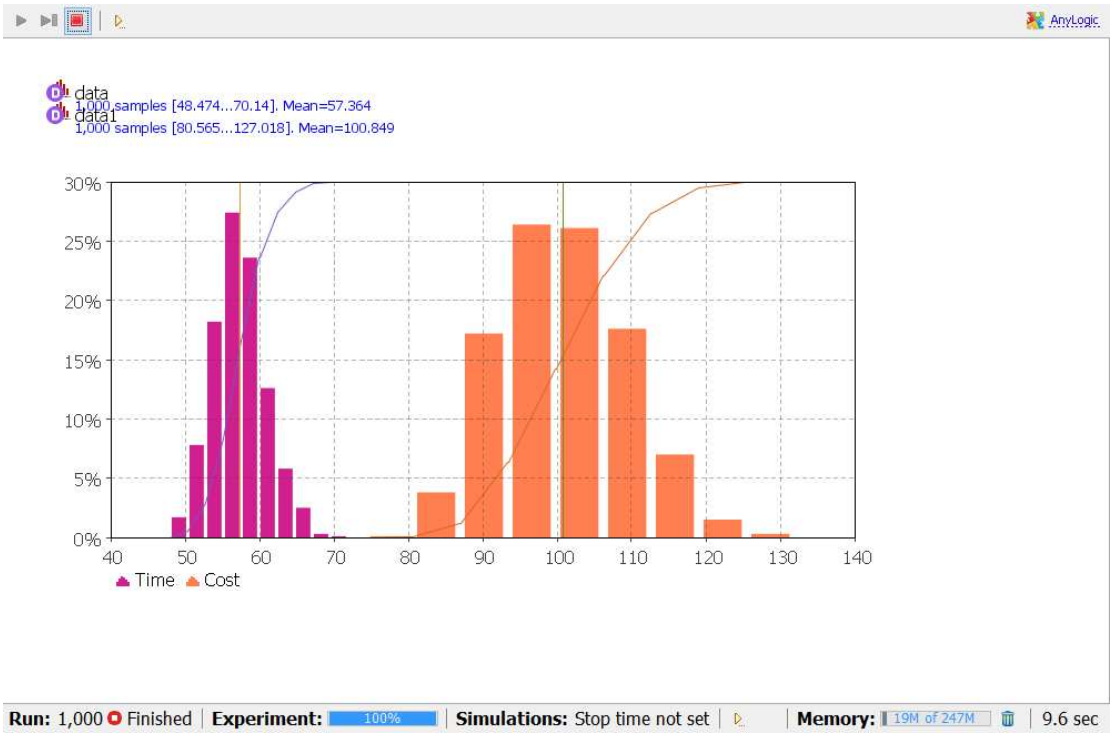
Appendix figure 3: Run simulation with no buffers

About the experiments, in order to minimize the final cost of the whole project, an optimization can be run; fixing the durations to the means, running the experiment obtains the optimal buffer allocation. In this case and contemplating that the AnyLogic Personal Learning Edition has some limitations, only 7 buffers can be optimized and only 500 runs can be done.



Appendix figure 4: Example of optimization

The second, running the Monte Carlo method, where in order obtain the distribution of values of the total cost, the experiment runs through the duration values of the distributions of the tasks. In this case has been run with the buffers in zero. The simulations run through the distribution of the durations and gets the distributions for the time and cost outputs.



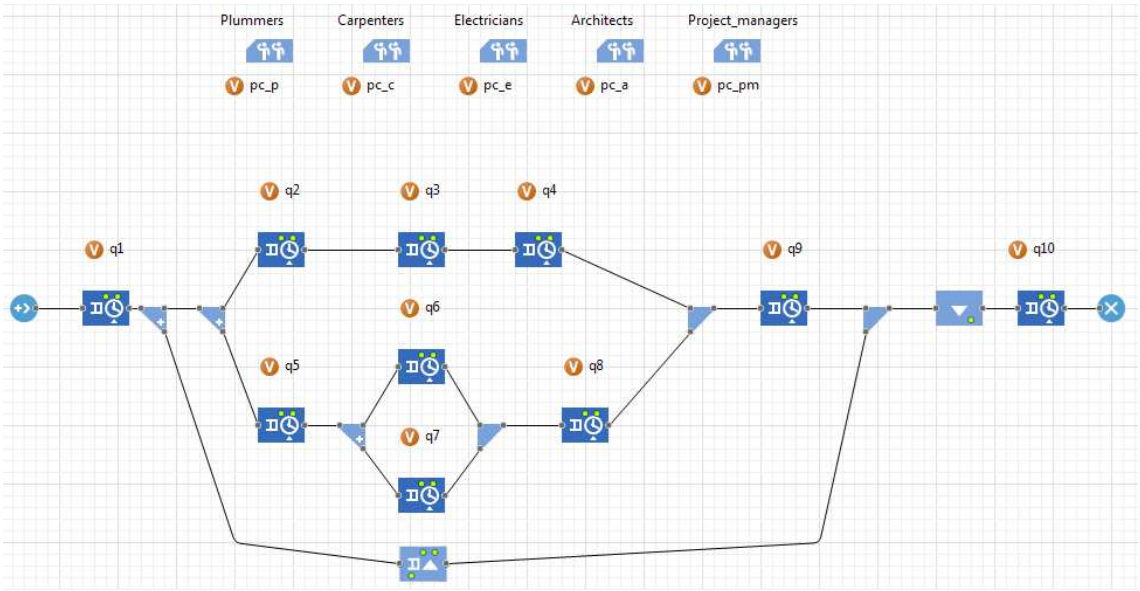
Appendix figure 5: Monte Carlo method

Appendix B

Model 2 – Adding more resources and quality

This model has the same basic lay out than the one before, but adding some more complex attributes that cover better than the one before the project network.

The resources are modeled so as it resembled more to a real system, for example to the construction of a house. Different human resources are implemented and grouped according to the characteristics of each one and later used according the particular necessities of the task.

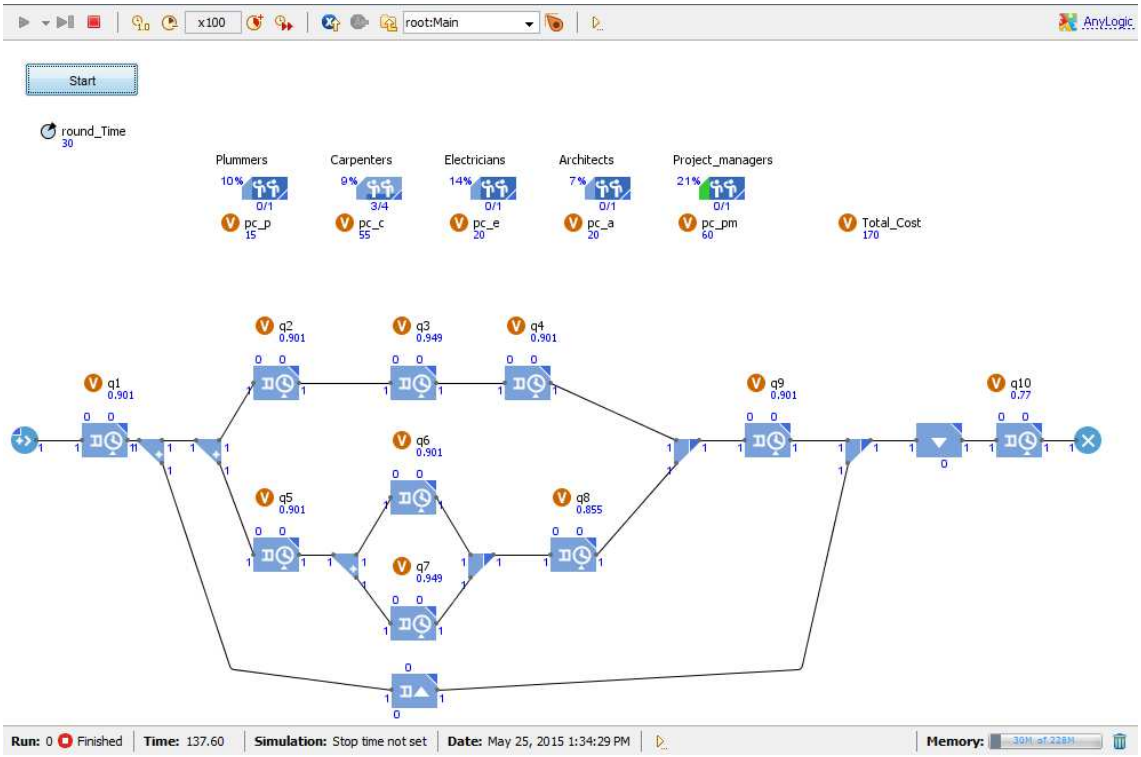


Appendix figure 6: Lay out and resource pools

For the paycheck calculation is necessary to identify who is working in each task, how long, and link it to that worker type's salary.

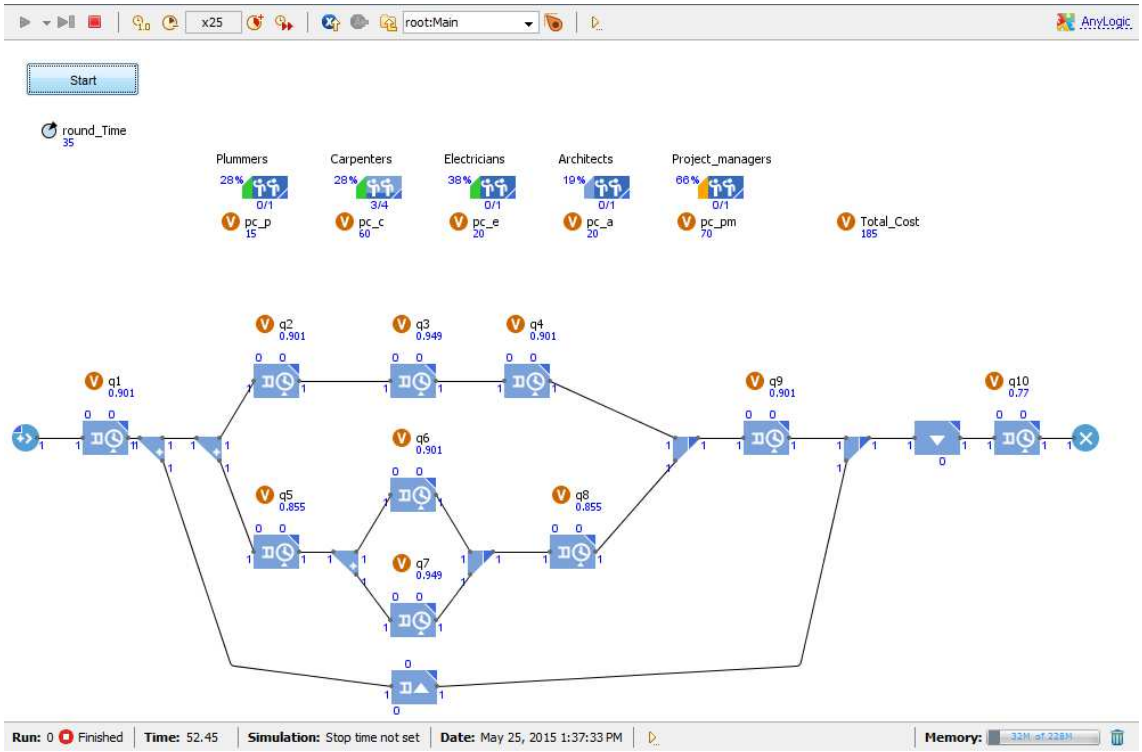
The quality aspect is included over each task, as a variable. Affects in the final quality value moves between 0, no quality, and 1, perfect quality.

The first experiment is run with proper worker allocation planning. Later on those workers will be distributed in another way so as to see how the outputs change.



Appendix figure 7: Outputs with proper worker allocation

In the next experiment, as in the second and fifth task are in parallel and they use to be two carpenters in each, one carpenter has been added to the second task. In the next figure the variation in the outcome can be perceived as the round time of the project its lower now, but the total cost of it has increased.



Appendix figure 8: Second experiment with extra resources

Appendix C

Project management simulation Workshop 13/05/2015
Feedback questionnaire

This form is going to be used as a feedback for the simulation model used in the workshop. The information collected will be analyzed and interpreted for the "The use of simulation to learn project business in a complex context" thesis. Thank you for participating!

- Did you know the theoretical background of the simulation model before?
- Have you used the AnyLogic software before the workshop?
- Did you feel the simulation exercise was beneficial? Why?
- Did putting the theory into practice help you to clarify any of the themes? Which ones?
- How do you feel about using simulation as an educational tool? Comparing to the traditional methods does it help you to get the knowledge easier?
- Did the models help you to understand the logic of the buffers, the project management and the complexities faced in real projects?
- Could AnyLogic software be used as an educational tool? Did you find it easy to learn how to use it?
- How would you improve the exercise? Or what would you add?