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A Systems Modeling Approach to Project Management: The Green Islands Project example

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Successful Project Managers understand in detail the customer requisites during project scope definition, avoiding therefore changes during the execution stage that will negatively influence the schedule, cost and quality of the project results. Unfortunately, the project manager and the customer have often different communication skills and scope changes are frequent throughout the project life. This paper proposes the use of Systems Modeling as a communication tool to allow the project team to illustrate potential project results to customers and better understand their expectations at the earliest stage possible. The implementation of this approach to the MIT-Portugal Green Islands Project clearly shows how it was possible to fill the gap between the customer and the project team in terms of the project objectives and requisites.

Key words: Engineering Systems, Project Management, Systems Modeling

1. Introduction

One of the key challenges in Project Management is to understand the customer expectations and manage them in order to define a reasonable and doable scope. The clear project vision of the customer shared during the preliminary scope definition in the project initiation process is usually not sufficient for the project team to define a detailed scope on the planning process. For the customer, it is difficult to foresee the implication of some decisions and constraints at this early stage and very often, customer satisfaction becomes a risk to the project. And this risk is particularly high in a project with a strong R&D component.

The roots of this imprecise dialogue are usually the different communication skills between the project's stakeholders: the project team has usually a more technical language and the customer a

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more business oriented language where the technicalities have a broader and misleading meaning. Thus, not only the customer does not understand the technical difficulties to implement his vision, but the project team does not understand at full extent the needs of the customer and the economic impact of delimiting the scope at certain levels. The current project management practices try to solve this with iterative discussions that last till the executing and control processes of project management. And many times, the project results do not match the initial customer vision even if it matches its functional needs.

Systems modeling is a very broad term that include various techniques and approaches to describe a system and predict its behavior, from simple flow charts to graphs, mathematical models or agent based modeling. In an era where modeling and simulation tools are widely available and it is easy to generate a model of a process using a simple piece of software, it is important to bring these tools to the table of a meeting during the critical phase of the project scope definition and develop the discussion using a tool that enables the stakeholders to test different product or service settings, analyze and compare the different results. A simple worksheet where one changes some numbers and automatically graphs the new results or a GUI that enables the customer to test different options, can largely decrease the communication gap between the customer and the project team in terms of projects expectations and requirements. At this stage, it is impossible to have a detailed model, but having a simple model is important to allow the discussion of different possibilities. That model is a communication tool, not a technical model for detailed design and the implementation.

This paper proposes the use of systems modeling approach during project scope definition and describes how this approach was applied to the Green Islands (GI) project of the MIT-Portugal Program (MPP) during the scope planning process with the customer - the Government of the Azores Region. The GI project´s objective is to design a new sustainable energy system for the Azores in order to decrease fossil fuel dependence. There are many possible ways to achieve this vision, but some of the constraints are difficult to explain, since the technical reality and the common knowledge are different. For example, it is difficult to explain why installing a large capacity of renewable energies *per si* will not be sufficient to cover all electricity production and still maintain security and service quality due to variability of this type of sources. But understanding this fact was a key point to convey the need for investment in other infrastructures and policies. It is therefore mandatory to level the communication between the government and the designers of such a system and could be very well pursuit using a systems modeling tool that showed the different effects and consequences of different scenarios. The paper describes how the project team developed the local energy system model before engaging into detailed discussions with the local stake holders and presets the results of using this approach to the GI project.

2. Project Management Initiating and Planning Process

2.A. The PMI standard up to end of 2008

The project management standard up to the end of 2008 [1] includes two processes in the project management "Initialization" group of processes: 1) Develop the Project Charter and 2) Develop Preliminary Project Scope Statement. The first process consists in a formal authorization of the project (through a contract or a protocol) and the second process includes the definition of what needs to be accomplished with the project and precedes the Scope Definition process at the Planning stage. This second process, described in detailed in Figure 1 should generate a document that addresses the characteristics and boundaries of the project and its associated products and services, based on the information provided by the sponsor. As defined by the standard, this document, which is static and is not changed throughout the project lifetime, has a crucial importance. It represents a firm commitment between the project sponsor and the project team about the project goals and boundaries and any scope management procedures, such as scope changes proposed by project sponsor or project team have to be discussed and agreed upon this document and are often a potential source of conflict.

The tools and methodologies described in the standard to execute this process focus on information systems to facilitate information exchange between the project stakeholders and project team, to manage changes and updates to any written document and to release of the final approved document. It also proposes the use of expert judgment from all stakeholders to evaluate the analytical and technical details in order to guarantee that the preliminary scope describes accurately what it is expected from the project and what is out of the boundaries.

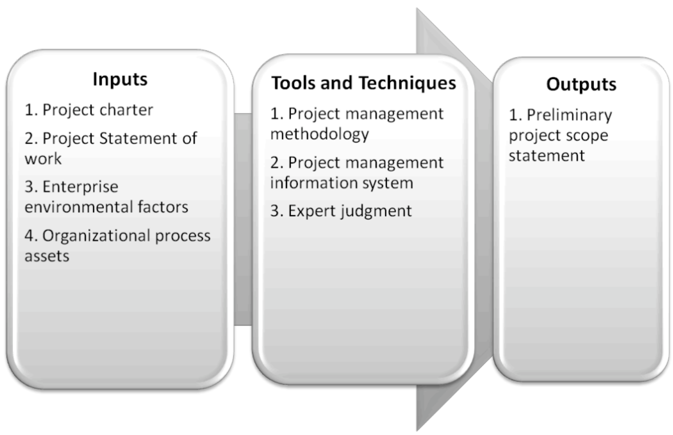

Figure 1 – Preliminary Scope Development Process as in [1]

At this early stage of the project, especially in a R&D project, the preliminary scope development is basically a communication process of the project expectations. Many times, the speakers of each stakeholder have different education backgrounds, different languages and even if the final agreed document is satisfying to all the parties involved, that does not necessarily mean that the final conveyed message is the same.

2.B. The PMI standard since the beginning of 2009

The latest project management standard PMBOK, released at the end of 2008 [2], presents significant changes to the initialization group of process. Again, it includes two processes, but the preliminary scope development process has been replaced by a "Stakeholder Identification" process, in order to guarantee that all stakeholders are involved in the scope definition process.

The Scope Definition Process is in this standard in now preceded by the "Collect Requirements" process, described in detail in Figure 2, which defines and documents the stakeholders needs to meet the project objectives. One may argue that in practice, the Preliminary Scope corresponded to the definition of the stakeholders' requirements, but the new standard goes further and introduces new tools and methodologies to guarantee an effective way to gather all the information to define the project scope.

The process proposes as tools and methodologies the use of one-o-one interviews with stakeholders to identify features and functions, focus group discussions and workshops with experts to clarify language and expectations, general discussions to identify, map and discuss ideas, questionnaires and surveys when stakeholders include broad audiences (like the population of a village), observations and finally prototyping.

Prototyping is described as a method to obtain early feedbacks on requirements by providing a working model or the expected product before building it. Since prototypes are tangible, it allows stakeholders to experiment with a model of their final product, rather than discussing only abstract representations of their requirements. Prototypes support progressive elaboration, based on iterative cycles of mock-up creation, user experiment, feedback generation and prototype revision until enough feedback cycles have been performed and the obtained requirements are sufficiently complete to move to the design or build phase.

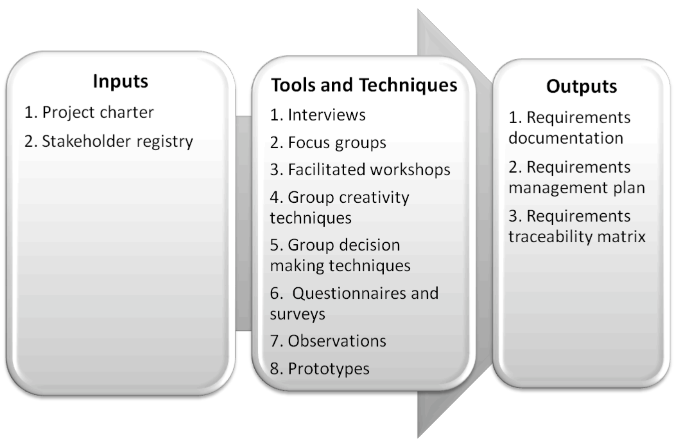

Figure 2 - Collect Requirements Process as in [2]

Even though prototyping maybe expansive and, as described in the standard, time consuming, it can save a lot of costs associated with changes at later stages in the project time life, as presented in Figure 3. An example of prototyping is the presentation of 3D models and or animations of new buildings that allow for stakeholders, such as governmental authorities, to evaluate the visual impact and use that information for project approval. Another example on information and communication projects, such as a software development, is the presentation of the main graphical user interface of the application for stakeholders to evaluate features and usability.

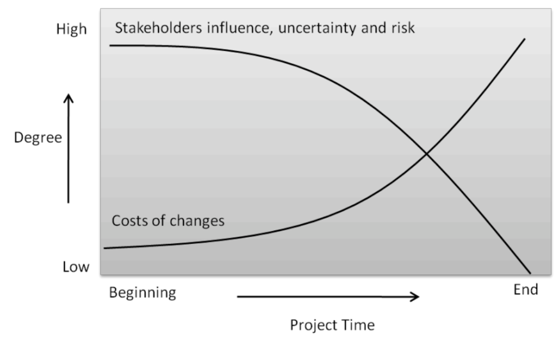

Figure 3 - Project life cycle costs, as described in [1,2]

In a R&D project such as the GI, prototyping is most of the times a stand-alone phase or task of the project. It is not as obvious what are the specific tools for it. Next section proposes system modeling as an approach to allow the use of prototyping for preliminary scope or collection of requirements processes in Project Management.

3. The Green Islands Project

The "Green Islands" project is a flagship research effort of the MIT-Portugal Program – an academic collaboration between Portuguese universities and the Massachusetts Institute of Technology (MIT) - in partnership with the Government of Azores and Portuguese companies in the energy business area. As described in the project charter, the objective is to design and implement a sustainable energy system that minimizes the dependence from fossil fuels and contributes to the economic and social development of the region.

The actual energy system of the islands of Azores is an isolated autonomous energy system with limited prospects of inter-connection due to the large depth of the sea and the diversity of the territorial dimensions. At the present moment the energy system is largely dependent on imported fuels for the diesel/heavy oil engines, exposing the region to the economic burden of fluctuating global oil prices. At the moment, 40% of primary energy is used for electricity production and 47% for transportation and only 6% is used in industry.

There is significant renewable potential in the Azores and the contribution of renewable energy sources (RES) to the region´s energy needs has experienced a large increase in the last years. Currently, RES account for 12% of the primary energy supply and 28% of electricity production, mainly from geothermal (22%) and less from hydro (4%) and wind (2%). The situation is diverse form island to island: the small island of Flores has 54% of its electricity produced by renewable energy (hydro and wind) and it had already several times during the year 100% production. The greatest island, São Miguel, has 47% of electricity production by renewable energy due to geothermal [3].

From the preliminary discussions, it was clear that the Government of Azores and the MPP team had different visions on how to define the GI project. Next sections describe in detail the different points of views.

3.A. The Government of Azores vision

The government of Azores and the local electricity utility EDA have an ambitious energy strategy that aims to achieve 50% of renewable electricity production in 2013 and 75% in 2018. It includes several investments in geothermal and biomass power plants in the biggest islands, São Miguel and Terceira, and several wind farms and hydro stations in the smaller islands. Another objective is to increase the renewable energy penetration in the primary energy up to 40%. However, this second objective is extremely hard to meet. Further, the Government of Azores has the ambition to use this change n the energy system as a motor for economic growth, job creation, economic activity change towards eco-tourism and high technology development and social welfare improvement of the region.

The government of Azores vision for the "Green Islands" was that the sustainability of their energy system was mainly dependent on their success on increasing the renewable energy penetration on electricity production and consequently on the primary energy consumption, by transferring some of the energy use, like GLP for water heating, into electric consumption. This has been so far their main energy strategic driver and their expectations for the GI project were mainly on designing innovative ways to maximize the use of renewable energy resources in order to achieve the strategic energy goals.

3.B. The MIT-Portugal Program vision

As the flagship project of the MIT-Portugal, an education and research program that aims at the development of the Engineering Systems concept, the "Green Islands" project is an opportunity to develop new methodologies and tools into the design and implementation of a complex system, such as the energy systems of Azores. In particular, this project is an opportunity to integrate research from different areas, such as social sciences and engineering, but also to apply them into different domains, such as Energy or Transportation. Therefore, for the MIT-Portugal Program, the "Green Islands" project goals is to have a diverse framework to develop innovative research on Engineering Systems.

In order to meet the specific project goals, MIT-Portugal has developed a three-part strategy for meeting Azores long-term economic, energy security and environmental goals. These three components are: leveraging locally available renewable resources, increasing end-use energy efficiency and designing advanced energy grids.

To maximize the cost-effective use of locally available renewable resources, their combined dynamics must be understood, and integrated with existing supplies to ensure secure and reliable electric power, as well as fuels for heating, cooling and transportation, either bio-fuels or electrical vehicles. Through a detailed understanding of how energy is used, now and in the future, it is possible also to radically reduce energy needs through investments in new equipment, well designed and integrated buildings, factories, farms and transportation systems, but also on policies that promote these investments. Finally, this dynamic transformation of how energy is used and supplied must be matched by investments in energy networks, especially in the integration with telecommunication and transportation networks to deal with the decentralized management framework that will emerge with the appearance of micro-generation networks or consumers that will become also producers. In this way, the project scope envisaged by the MPP team was much broader and ambitious that the government one.

4. Systems modeling to Project Management – An Engineering Systems Approach

Project Management has always been a holistic discipline - its practice has long been promoting the use and integration of different tools and techniques from engineering but also management and social sciences [1, 2]. Over the last two decades, its body of knowledge has been evolving continuously and it is expected that a good project manager possesses not only technical but specially leadership and communication skills. Project Management is itself a good example of an Engineering Systems methodology for design and implementation of complex systems [4]. On the other hand, the engineering systems approach, which promotes the use of tools from management and social sciences in engineering problems and vice-versa, can definitely improve project management practice, by using an engineering tool such as systems modeling to solve a communication problem.

Nowadays, it is very easy to have access to modeling tools in a specific domain, such as Energy Plus to model energy consumption in buildings [5], or to have access to a general tool that enables one to model any type of system, such as Matlab [6]. Many of these modeling tools, like the first example, are freely available on the internet [5] or, as in the second example, are standard softwares in industry [6]. Therefore, the learning curve of these tools is usually very steep and it is possible to develop a simple, realistic model in a very short time.

When a customer describes its vision of the project, it is for him very clear what the expected final result is. However, the way he believes that will get him there is either misleading or unknown. On the other hand, project teams tend to focus on the way to achieve the results, since this will provide the guidelines to define the project plan. And this is when the communication process, between what is the goal of the project and the way to achieve it - i.e. the project scope - starts to fail. It is important for the project team to have on the discussion table, as early as possible, a way to quickly generate a set of possible project outcomes, not only to understand if they match the customer's vision of the project, but at the same time to understand what are the requirements to achieve this goal. And a model of the system that will be developed in the project, whether it is a building, a machine, a software or a policy, can easily correspond to the prototype tool described in [2]. Next section describes how this approach was used with success in the Green Islands project.

5. Application to the Green Islands Project

As described in Section 3, the Government of Azores vision for the Green Islands Project was different from the vision of the MPP project team. While the government of Azores focused on the increase of renewable energy resources penetration on electricity production and consequently the primary energy, for MPP team the increase on renewable penetration was only a part of the necessary strategy. The remaining vectors of the strategy - energy efficiency and networks modernization - was generally understood and supported by the government, but the relative importance of it compared to the increase on renewable penetration was considered to be low. This was the main gap between the two visions and it was important to diminish this gap to avoid the lack of support during project implementation to energy efficiency and infrastructure investment measures and policies. This was acknowledge right from the start by the project management team and the defined strategy to overcome this problem was to model a set of scoping scenarios, that described the different visions of the project, compare the results and use this information as the basis of discussion on the scope definition meeting. Therefore, the MPP team first task was to model the energy systems of São Miguel using the energy modeling tool TIMES [6] before the kick-off meeting of the project, which occurred in January 2009 [8].

5.A. The TIMES model

The TIMES model (an acronym for The Integrated MARKAL-EFOM System), was developed and is maintained by the Energy Technology Systems Analysis Programme (ETSAP) [7], an implementing agreement under the aegis of the International Energy Agency (IEA). TIMES is a model generator for local, national or multi-regional energy systems, which provides a technology rich basis for estimating energy dynamics over a long-term, multiple period time horizon. It is usually applied to the analysis of the entire energy sector [9], but may also applied to study in detail single sectors (e.g., the electricity and district heat sector) [10].

In TIMES, reference case projections of end-use energy service demands (e.g., car road travel, residential lighting, steel production and the like) are provided by the user for each region. In addition, the user provides estimates of the existing stock of energy related equipment in all sectors in the base year, and the characteristics of available future technologies, as well as present and future sources of primary energy supply and their potentials. Using these as inputs, the model aims to supply energy services at minimum global cost (more accurately at minimum loss of total surplus) by simultaneously making decisions on equipment investment, equipment operation, primary energy supply, and energy trade. TIMES is thus a vertically integrated model of the entire extended energy system. The scope of the model extends beyond purely energy related issues, to the representation of environmental emissions, and perhaps materials, related to the energy system. The model is well suited to the analysis of energy environmental policies, which may be represented with accuracy thanks to the explicitness of the representation of technologies and fuels in all sectors. In TIMES, the quantities and prices of the various commodities are in equilibrium, i.e., their prices and quantities in each time period are such that the suppliers produce exactly the quantities demanded by the consumers. This equilibrium has the property that the total surplus (consumers plus producers surpluses) is maximized.

In this case, TIMES model was used to describe the actual energy system of the island of São Miguel for different sectors (electricity production, transportation, industry, services and commerce and residential) and predict future scenarios that describe different investment and policies.

5.B. The scoping scenarios for the Green Islands

To initiate the project scope discussion with the project sponsor, the MPP team developed 5 different scenarios that described different project scopes:

- **BAU** (Business As Usual) – this scenario describes the government actual investment plan under the assumption that the electricity and primary energy yearly growth rates follow the actual trend;

- **MPPRen** (MPP Renewables) – this scenario describes a severe increase in the renewable energy resources penetration, with more geothermal and hydro production, as expected by the government of the Azores, in particular with the adoption of a storage system;
- **MPPRenDom** (MPP Renewables and Domestic) – this scenario is equal to MPPREn but it also considers the adoption of a energy efficiency policy in the residential sector that promotes the substitution in 10% of the households of appliances with energy efficiency grade B to grade A (more efficient);
- **MPPRenAll** (MPP Renewable and All Efficiency) - this scenario is equal to MPPRenDom but also considers the adoption of other energy efficiency policies that allow to decrease the electricity and primary energy yearly growth rates to 2% and 1% only;
- **MPPRenAllEV** (MPP Renewable and All Efficiency and Electric Vehicles) – this scenario envisages a 20% penetration of electric light duty vehicles in the total vehicle fleet, on top of the MPPRenAll scenario.

The idea of these 5 scenarios, described in detail in Table 1, was to show the relative importance of promoting actions on energy efficiency and modernization of energy networks (with storage and electric vehicles) in comparison to the increase in the penetration of renewable energy resources vision.

Table 1 – Scoping scenarios

	Geo (MW)	Hydro (MW)	Wind (MW)	Biomass (MW)	Storage (MW)	Elect. GR (%)	Energy GR (%)	Domestic Gains (%)	EVs (%)
BAU	37	5	9			4	5		
MPPRen	47	9	9	10	15	4	5		
MPPRenDom	47	9	9	10	15	4	5	10	
MPPRenAll	47	9	9	10	15	2	1	10	
MPPRenAllEV	47	9	9	10	15	2	1	10	20

The results presented in Figure 4 - Electricity production for different scenariosFigure 4 and Figure 5 describe the scenarios for electricity production by source and primary energy consumption by type of fuel for the year 2013 and 2018, the reference years of the government energy strategy.

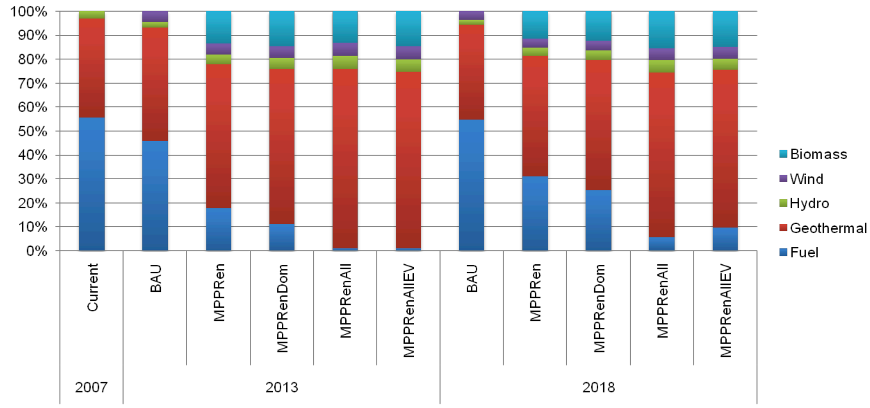

Figure 4 - Electricity production for different scenarios

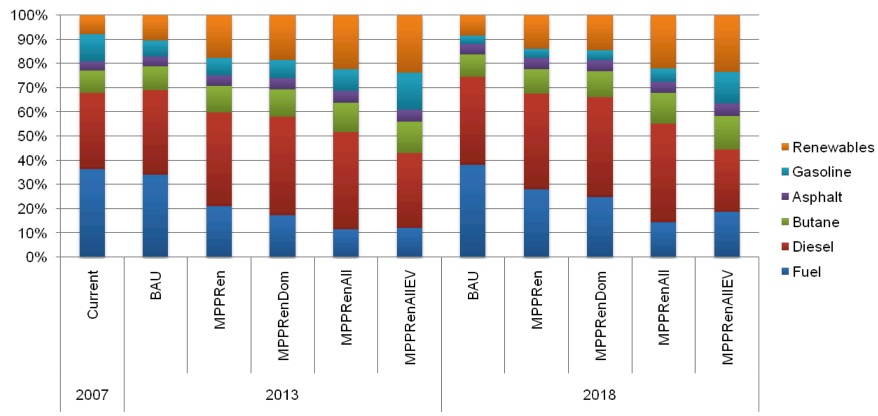

Figure 5 - Primary energy consumption for different scenarios

6. Results discussion

On the kick-off meeting in January 2009 [8], the MPP team presented the results described in the previous section. The fundamental discussion that had to be made at that point was that the sustainability of the energy system in Azores depends much more on effective energy efficiency policies and investment on the modernization of the energy network - e.g. with the introduction of electric vehicles in the islands - than on the increase of renewable energy resources for the production of electricity.

As it can be observed in Figure 4, the scenario with increasing renewable energy (MPPRen) will be able to satisfy the government requirements in terms of electricity production (75% of renewable production in electricity) in 2013. However, if no measures are taken up to 2018 in terms of energy efficiency, the penetration will decrease for 70%. And a simple measure like the replacement of 10% of the appliances of grade B to grade A would be enough to maintain in 2018 the renewable penetration in 75%. Further, if more aggressive measures are taken, not only on the electricity consumption but also in the transportation sector, it is possible to achieve in 2018 a value of 95% of renewable penetration in electricity production in the MPPRenAll scenario or 90% in the MPPRenAllEV scenario.

Nevertheless, the results in Figure 5 show clearly that to reduce severely the weight of fossil fuels in the economy, it is necessary to reduce significantly the energy consumption growth rates. For example, the introduction of electric vehicles will allow the reduction of gasoline and diesel consumption in the transportation sector, even if it is necessary to increase slightly the electricity production using fuel.

These results enable the MPP team to convey the message to the Government of Azores that a sustainable energy system does not depend only on the renewable energy resources, but mostly on energy efficiency measures and modernizing the energy networks. Therefore, the Green Islands project scope should include actions towards the implementation of energy efficiency policies and should consider investment plans on networks, such as energy storage systems and electric vehicles. As for the renewable penetration line of action, the actual investment plan could and should be more ambitious, but the planned actions are already on the right direction.

The use of the TIMES model results allowed the meeting participants to engage on detailed discussions around many important topics to develop a sustainable energy system, beyond the trivial discussion on renewable energy resources. It is however very important to emphasize the significance of the modeling tool in this process. The presented results for the reference and BAU scenarios, which had already been modeled by local agents using different tools, gave to the local stakeholders a high degree of confidence on the results of the new scoping scenarios proposed by the MPP team. If this had not been the case, the use of the modeling tool would not have help at all to cover the gap between the different points of view.

7. Conclusion

This paper proposes the use of system modeling tools to help project managers to develop early projections of the project results in order to clarify customers' expectations and requisites for the project. This approach fits the project management practices and this paper discusses the evolvement of the standards towards the need for prototyping. As described in the case study of the Green Islands project, the use of this approach allowed to merge the sponsor's and the project team's different visions of the project and avoid future misunderstandings and changes to the scope of the project.

The implementation of this approach relies on two important premises. First, the project team has to be able to quickly develop a model of the system and for that, a tool with a steep learning experience curve or, preferably, a tool known by the project team should be chosen. Second, the developed model has to be recognized by the customer has a reliable model. For this, it is necessary that the model results describe a reality already known by the customer.

To validate the usefulness of this approach in project management, it is necessary to introduce in project management control processes, such as scope control, a comparison between the project results and the results predicted in the prototype, particularly in terms of redefinition of requirements by the customer. Therefore, during the development of the Green Islands project, the results of the prototype model will be extensively compared to the project implementation results.

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