TESIS DE MÁSTER

Máster

Ingeniería Estructural y de la Construcción.

Título

"Application of System Dynamics to model rework in construction projects".

Autor

Néstor Eduardo Ramírez Cruz.

Tutor

Nuria Forcada Matheu.

Intensificación

Construcción.

Fecha

Febrero 2014

TESIS DE MÁSTER

Máster

Ingeniería Estructural y de la Construcción.

Titulo

"Application of System Dynamics to model rework in construction projects".

Autor

Néstor Eduardo Ramírez Cruz.

Intensificación

Construcción.

Fecha

Febrero 2014

Abstract

When a certain project is completed, a process of feedback is the next step to isolate the mistakes and failures occurred in it. This process is meant be done following certain methodologies that can use the mistakes and failures to grow in experience, improve the success rate in the future projects (of any kind of complexity) and avoid any source of possible rework.

In this master thesis it will be analyzed the incidences that took place inside a residential project developed in Dominican Republic around 2010. The project is divided in three different stages; first, construction defects during the development of the first group of houses under a previous contractor. Second, incidences related to repair tasks to correct construction errors made by previous contractor while final customers were already living in the houses. These repair works were performed by a new contractor. Third and last, construction incidences related to development of a second group of houses that were already started, but were going to be finished and delivered by new contractor management,

The main purpose of the study is to see how these variables interact all together and their contribution to rework arise. Also, a plus of this case study is to see how customers behave after receiving final product and the problems that could arise in post-deliver stage.

Rework behavior is going to be study and analyzed through System Dynamics, a modeling tool that helps to understand the structure of any complex system as well as its operational dynamics underlying during the life cycle of the project. The main idea is to see if intangible variables (stress, lack of confidence and uncertainty) linked to tangible variables could eventually increase the amount of rework occurred within the project. The interaction of factors is going to be modeled through a simulation software to observe rework's outcome behavior.

Finally, after having developed and analyzed the system dynamics models on construction and repair stages, several measures are discussed. The most important part is how all incidences causes interact with each other and identify which ones could affect directly in the amount of rework produced in the project.

Keywords: rework, construction, repair, System Dynamics, modeling, simulation, system thinking

Acknowledgments

It is merely important for me to express my gratitude towards all the people responsible for my preparation and growth in my professional career and personal life during my stay in the lovely city of Barcelona. First of all, I want to thank God for enlighten me through this stage of my life and giving me the strength and dedication to culminate this part of my formation and not giving up in all those times life got difficult and I couldn't see further in time for a solution.

Thankfulness to the Ministerio de Educación Superior (MESCYT) for the support and the opportunity to continue my growth in my professional career. Also to mention the Banco Nacional de la Vivienda (BNV) for the economical support through their scholarship loan program.

To my thesis advisor, Dra. Nuria Forcada, for introducing me to this interesting subject and that, without your support and guidance, the production of this master thesis couldn't have been conceived and elaborated. It's incredible how a small idea shifted during these months of hard work. Thanks for receiving me in your office, even though you were busy with your own work, always found a little space of time to clear my doubts.

To Natalie, my fiancée, I thank you for the patience you had during this time while being apart. With your persistence, help and advice, I could concentrate and apply myself to work hard and elaborate a fine quality document.

To my family for their unconditional support during my whole life providing me with a great academic and personal preparation, so I can be who I am now; a self-sufficient person that can adapt to any situation that life present's me. Also to push me to apply myself harder and pursue this dream of prepare myself abroad and live new life experiences.

To my cousin Luis José Medina and his family for receiving me in a new city, offering me a place to live and helping me on getting myself around the city while I adapted to this major change of leaving my hometown.

To my friends Francis Leguisamón, Ronnie Maldonado and Ricardo Calderón for encouraging me, through their own experiences, to do this master and live a brand new life experience, and counseling me . And, last but not least, Jonathan Rincón, Mauricio Rodriguez, Juan José Tejón, Celio Marte, Jaime Montelongo and Óscar Alarcón for being the best classmates and friends, with whom I shared life events and helped me making this experience in Barcelona the most pleasant and happy time ever.

To the Universitat Politècnica de Catalunya faculty and the rest of friends whom I shared during this time...

...Thank you all.

Table Of Content

1. Chapter 1: Preface

1.1. Introduction

There is little information on how rework behaves within construction projects, and more important, which parameters intervene and control its final outcome. Using only traditional method it's almost impossible to keep track of what is really happening inside the project and locating the original source that allows rework arise. Only when several situations such as budget overruns, slow progress in task finishing and other latent situations, apparently hidden, start occurring and management can't identify any reason whatsoever.

The aim of this Master thesis is to identify the major reasons that contribute to the emergence of rework on any given system and help to answer the question "Why do projects continue to perform poorly in spite of advanced tools and techniques used in project management?".

Trough a case study related to the development of a residential project in Dominican Republic, incidences related to construction process are going to be grouped and classified according to the causes that have generated them. Also shall specify who was the responsible involved and the subsequent amount of time and/or cost increase, if applicable. Incidence list includes all kind of qualitative and quantitative data present during the course and progress of works.

In addition, this case study presents, from the perspective of the house owner or customer, the status of the project after construction is completed. This section includes the repair of all defects in work which were not corrected during construction phase. Customer's presence and already living in house will be a key factor while addressing repair tasks

After having classified all incidences, using System Dynamics a diagram is going to be elaborated to show the interaction between all incidence causes laid as variables and factors, with the purpose of showing how rework arise and evolve during the life of the project. One point of importance is including qualitative data (such as stress, demotivation and uncertainty) that can't be measured, but still have a key role in rework's outcome behavior. These statements are going to be corroborated with the help of simulation tools that allows to observe how rework's behave on both environments.

Finally, after completing this section, it's possible to obtain conclusions from rework's conduct to reduce or even eliminate these events in future projects, because reducing rework involves a feedback process of identifying its origins and causes, with the sole purpose of developing an understanding on how these sources and causes are interrelated and interact between each other's and applying these concepts into future projects of any kind.

1.2. Objectives

1.2.1. General Objectives

The main objective of this Master Thesis is to contribute in determining the causal structure of rework in construction projects, by analyzing the incidences in "The Club Residence Guavaberry" project in Dominican Republic, as a Case study. The final purpose is to define the causes of rework in residential projects and determine the parameters to reduce it in future similar projects.

1.2.2. Specific Objectives

- Determine and group which parameters are the most relevant and influence directly in the rework of residential projects.

- Using System Dynamics modeling software', observe how these parameters interact, and monitor model's behavior through a live-feed simulation that reproduce the impact on the amount of rework produced during the life of the project.

1.3. Methodology

1) Carry out literature review about the definition of rework, system dynamics and the components and ideas that form these concepts. In this part is important to point out differences and similarities between all concepts exposed.

2) Explain the current situation in Dominican Republic and factors, that might affect the construction and the institutions and organizations in charge of regulating this sector.

3) Select a single project that meets certain specifications, such as determined demographical size, complexity, diversity of subcontractors, workshops, representative budget, etc. This is so the interaction and relationship between all the different parts can be appreciated in a more complete level. The methodology used for developing this master thesis includes a case study and gathering necessary information, along with relative rankings and conclusions. The aspects involved in this part are:

   3.a) Case of study:

   A case study approach is based on analytic induction and is used to examine the underlying dynamics that may contribute to rework. A case study is exploratory in nature, based on interviews and heavily depends on verbal reports and observation data. This methodology should be used to investigate the technical aspects of a contemporary phenomenon within a real life context (Yin, 1984). A case study can provide analytical rather than statistical generalizations and can capture the complexity and dynamism of an organizational framework projects (Flyvbjerg, 2006).

The case study used in this study corresponds to a residential project. Within the contract , it contains a large number of works or subprojects related. The biggest appeal of the analysis of this project is that projects of a similar nature are developed each year in major places of residential demand in Dominican Republic. This means that being able to detect the incidents presented in this particular case, could be improved to a great extent the rest of the other projects, from conception stage to final delivery.

3.b) Data Collection

The methods used for data collection in this research are observation, interview and document analysis. Yin (1994) provides up to six data collection methods or "sources of evidence", as he calls it: documentation, archival records, interviews, direct observation, participant observation and physical objects. Even so, it can be summarized in the three types outlined above as archival documents, physical objects, personal documents and photographs can be considered in the documents section.

3.c) Data analysis

Firstly, to elaborate a list of all the incidence that happened during the project's life, grouped according to its nature and divided in smaller parts for easy understanding.. About the information of the works done within the project, these will be classified with greater emphasis on that which refers to errors or changes that caused a direct impact on the work, whether small or significant. The main goal is to try to find all the causes that led to these incidents or deviations concerning the programming works and how they were solved and its aftermath. Incidents that generated rework, causing extra costs and/or delays in the work, will be analyzed in depth, finding their causes, responsible, and increases caused.

It may be noted that in some cases, cost increases correspond to poor execution and, therefore, should be borne by the contractor, in others it will be because of unforeseen or omissions in the original project development and will come to be part normal development of the project, and others, to a lesser extent, is cause for mismanagement of the auditing, and must be borne by the customer.

With the previous list made, the next step is defining the parameters that influence rework in construction projects. The main purpose is to isolate the common factors from the list to create the System Dynamics graph, to show the interaction between all of them.

Create a System Dynamics model of "The Club Residence Guavaberry" project based on parameters extracted from the list of incidences showing the Rework Cycle. Afterwards, create a live model based on the SD model to simulate, in real time, the interaction between all parameters to show the influence in the amount of rework produced during project, and which ones are more relevant in rework produced.

Last, expose the conclusions obtained from this thesis. After analysis, ideas will be debated on the subject, which will make recommendations for future projects and conclusions will be drawn, with the possibility to extrapolate to other fields of action different and determine how rework can be reduced

1.4. Terminology

Rework: this can be simply defined as the unnecessary effort of re-doing a process or activity that was incorrectly implemented the first time. (Love & Edwards, 2004)

System Dynamics: is a method for modeling and analyzing the behavior of complex social systems over time. It has been used to examine various social, economic and environmental systems, where a holistic view is important and feedback loops are critical to understanding the interrelationships. (Rodrigues & Bowers, 1996)

Simulation: is the imitation of the operation of a real-world process or system over time. The act of simulating something first requires that a model be developed; this model represents the key characteristics or behaviors of the selected physical or abstract system or process. The model represents the system itself, whereas the simulation represents the operation of the system over time. (Banks, Carson, Nelson, & Nicol, 2001)

Project scope: is the part of project planning that involves determining and documenting a list of specific project goals, deliverables, tasks, costs and deadlines. (Rouse, 2012)

Nonconformity: it's an activity that has been performed improperly and results in a deviation from a specification, a standard, or an expectation that is not contained in the contract documents, and becomes a disadvantage for the completion of a process at any point of development. (C. Dorf, 1999)

Incidence: is a term describing the activities of an organization to identify, analyze, and correct hazards to prevent a future re-occurrence. Cannot be considered a nonconformity, although its solution could lead to a rework. (Terms, 2010)

Cost overrun: also known as a cost increase or budget overrun, is an unexpected cost incurred in excess of a budgeted amount due to an underestimation of the actual cost during budgeting. (Standish, 2004)

Holistic: methodological position that states systems along with all their properties should be analyzed as an integrated total, and not by separated parts. (Oshry, 2008)

ITBIS: tax on Industrialized Goods and Services is a tax applied on general consumption value added type applies to the transfer and import of industrial goods as well as service delivery on any economic transaction in Dominican Republic. (DGII, 2008)

2. Chapter 2: State Of The Art

2.1. Understanding a typical project

"Complex" is, perhaps, the word that could most accurately define the projects realized in this new era since the decade of 1930, specifically after World War II. Nowadays, it seems time and financial funds to create, conceive, design and build any given project is more constraint than the past, but on the other hand technical specifications are required to be more specialized.

In present days, construction industry faces more difficult, complex projects to accomplish, and are required to be completed in a very tight schedule with no error margin. These "cutting edge" projects, however, are done under traditional management methods, which are unable to provide the right tools to successfully complete the task.

Traditional methods functions on the basis that the system on demand functions on a "linear" sequence, managing only the quantitative data that can be measured. In other words, the management staff is expected to have all the information beforehand at the moment of beginning the project and can anticipate all the misleading events that can affect budget or schedule. This idea has proven not to meet the expectations in several times.

This essentially means, traditional project management methods implies that order should be imposed from above (leading to top-down command and leadership) and that structures should be designed to support decision-makers (G. Rodriguez & M. Williams, 1998). (Love, Goh, & Han, 2010); (Wiliams T. , 1999).

According to (Lyneis, G. Cooper, & A. Elsa, 2001), in an ideal project, staffing follows the plan and increases to a peak, then falls off as the work is completed. In reality, however, project staffing is often slower to build up than planned and frequently exceeds planned levels for an extended period, commonly known as the overrun. On most projects, managers also assume, either explicitly or implicitly, that productivity will remain constant over the duration of the project. This behavior is presented on Fig. 2.1.

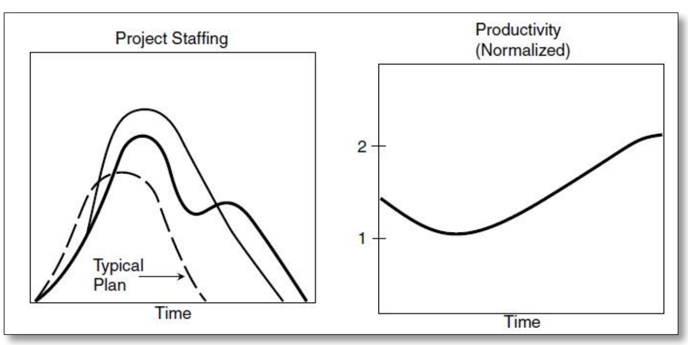

Fig. 2.1: Dynamic of a standard project.

In reality, productivity typically falls from the beginning through the middle of the project, before rising at the end. Productivity often varies by a factor of two over the course of a project. This real behavior is shown in Fig. 2. 2.

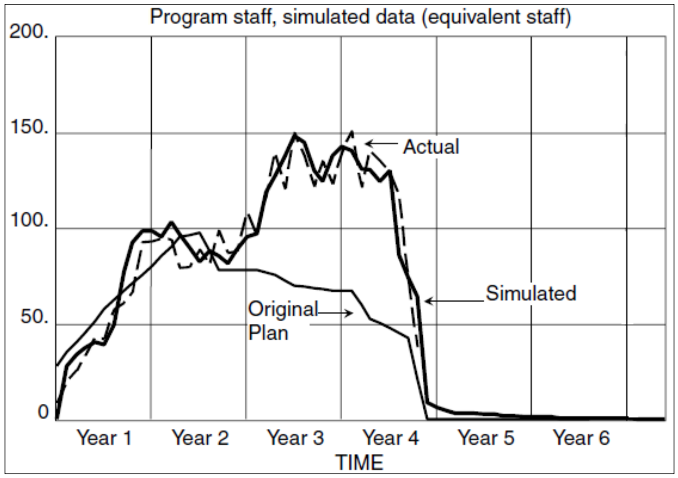

Fig. 2. 2: Staffing behavior in reality.

At the same time, the economical distribution of the project consist on balance the cash flow with equal disbursements during the time of execution in several group packages. But before even starting the construction phase, there is a initial expense with planning and designing, paperwork for permits.

Contrary to staff development behavior, cost behavior tends to have a strong activity due to funds disbursements at the beginning to deal with all the problems associated with the project start. It's not until the "break-even point" when the situation starts to stabilize. Fig. 2.3 shows the economic behavior of a project, with its break-even point marked in red dot.

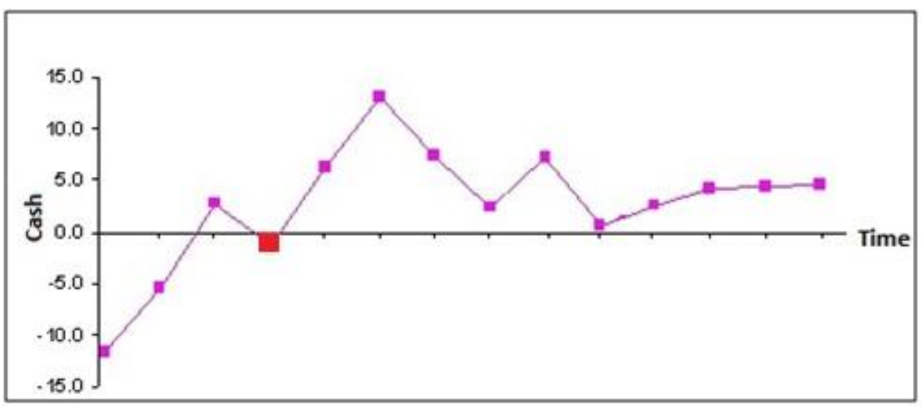

Fig. 2.3: Example of economical behavior on a construction project

However, as projects become more complex in nature, this philosophy is deemed ineffective in reducing project failures and assuring project success. Inherent within complex projects are unintended consequences and counterintuitive outcomes due to the structural complexity and uncertainty that prevails (Love & Edwards, 2004); (Love, Goh, & Han, 2010).

In terms of (Baccarini, 1996) and (Williams T. , 2002) structural complexity is derived from the interaction between the number of elements that form the project and their interdependence. Uncertainty is derived from a lack of clarity concerning project goals and an absence of appropriate means with which to achieve them. The result is that project elements interact in complex and unpredictable ways, which can increase the likelihood of having to repeat activities and tasks that should be done correctly on a first try (Hoedemaker, Blackburn, & Van Wassenhove, 1999). This situation is further exacerbated when activities are undertaken concurrently due to issues associated with schedule pressure.

After explaining the possibility of this situations emerging in the system, there is no chance of understanding how or when these kind of situations arise, and even worst, to control this kind of behavior only using traditional tools and methods.

2.2. Defining rework

When incidences grow within a project up to a certain level, team work, in an effort to meet a project's schedule completion date, bring additional resources that could be employed, but such actions may cause effects contrary to desired expectations (McConnell, 1999). By pushing beyond the limits of concurrency, complexity increases, which can delay completion of tasks, particularly when revisions, repairs and extra works need to be executed for emending activities incorrectly done the first time done. This is a phenomenon named "Rework" (Firedrich, Daly, & Dick, 1987); (Burati, 1992).

Rework is known to be a problematic issue present in every construction and engineering projects. This incident can arise from multiple causes such as design changes, errors and omissions that often stem from scope uncertainty and the contracting strategy adopted (Love, Goh, & Han, 2010); (Ackermann, Eden, & Williams, 2005); (Ackermann & Eden, 2005); (McMaster, 2000); (Love & Edwards, 2004). According to (Love, Mandal, & Li., 1999), rework is a waste of time and resources that has become an accepted part of the construction process. The personal involved in the procurement of buildings invariably do not realize the extent of rework that actually occurs.

According to (Love, Goh, & Han, 2010) one challenge to overcome in most construction and engineering projects is that the information available to staff is often incomplete and ambiguous and the consequences of people's actions are highly unpredictable and uncertain. The interfaces that exist between project participants are complex and require detailed communications between all different work teams

The project team is invariably subjected to increasing pressures arising from project complexity. Further the need to manage complexity leads to a paradox of consequences or negative feedback loops. As project complexity increases, there is a proportional increase propensity for details to be missed or simply not undertaken.

Frequently, the feedback from an event is deemed ambiguous as it contains multiple viewpoints and interpretations as to how it occurred. Often post-event adjustment takes place in a highly charged or political environment where blame is sought (Love, Goh, & Han, 2010). Purely focusing on blaming an individual or attacking their ability to perform tasks may have detrimental consequences to learning and solving the primary reason of rework's arising.

At a certain point, organizations and individuals frequently rely on previous behaviors to which they are conditioned; deleting old decision-making criteria can be very difficult. Although organizations will sometimes unlearn, and perform meta-level shifts by restructuring the linkages between stimulus and responses, these shifts often appear to be temporary. But, old habits soon return when pressures to meet unrealistic cost and schedule forecasts are required to convince customers of a project economic viability and success.

Additionally, faulty reporting from those individuals who had tried to distort the truth prevents objective analysis for the situation. In addition, secrecy or the failure of internal communication due to restrictions on information flow prevents learning from taking place.

Nevertheless, it's important to understand how rework events are viewed and understood by individuals and as a group inside the project. This behavior will influence their ability to learn and adjust (Love, Goh, & Han, 2010). Addressing the underlying conditions of problems and understanding how variables interact to produce an event can provide the foundations for a new view of the project system, which may result in the adjustment of an individual's and group coping mechanism.

Rework can adversely influence project's participants in different ways. Learning tends to occur at different levels within project based organizations. Therefore, it is suggested that learning and adaptation procedures should be driven by project team members who can act as catalysts to spur organizational learning through social interaction, and diffuse knowledge accordingly about rework causation. It's a major success from management office to take advantage of cross communication without boundaries between different work teams where an exchange of information takes place on a wide range of issues such as quality, environmental management, safety, and outcomes experienced from previous projects aiming to overcome present difficulties

Causal attribution after an error happens is deemed necessary to obtain knowledge about events for the purpose of undertaking subsequent actions. Assigned causes can lead to considerable differences in future behavior. Behavior after error occurrence is influenced by the presentation of positive error heuristics which are presented to facilitate emotional coping after error occurrence, thereby aiding people to consider that errors can also be interpreted as informative feedback.

It has been shown that error management training leads to more functional task behavior such as more requests for assistance, less frustration and better performance.

If rework is not identified and its costs formally measured, it can become increasingly difficult to learn to mitigate its occurrence. The existence of uncertainty avoidance restricts critical analysis and learning from taking place. In addressing this issue head on, rework should be incorporated as a key performance indicator and linked to a risk/reward incentive scheme.

Sadly, as in today, there is still little systematic knowledge available about the dynamics of rework in complex projects, despite the fact that they frequently exceed budget and schedule projections by 20% to 400% . The causes of rework could be extracted and identified from the direct experience of the labor personnel involved in the project, but the underlying dynamics, relationships and consequences can vary significantly depending on the point of view of studying all the facts

2.3. Causes that lead into rework

In construction management field, there are several methodologies and different points of view that explain the different causes or incidence that could lead eventually into rework arise within a project. Also, the following methods help explain how to classify these causes according to nature or generalized and common parameters.

First of all, raising awareness about the reasons contributing to rework in projects of any nature requires multiple perspective from experienced personnel to understand what is really happening. (Ackermann, Eden, & Williams, 1997); (McMaster, 2000); (Ackermann, Eden, & Williams, 1997)

According to (Love, Goh, & Han, 2010), within building and civil engineering projects, rework has been generally attributed to latent conditions in organizational and project systems.

Such latent conditions tend to reside in systems until errors are apparent; whilst unidentified participants remain blissfully unaware of the impact that particular decisions, practices or procedures can have on a projects performance. Also, these hidden errors play a critical role and influence individuals to commit mistakes that produce immediate events. Organizational issues such as management policies and the work environment can provide the conditions for designers‟ deficiencies to manifest as mistakes, violations and incompetence. (Love, Goh, & Han, 2010)

One of the most critical incidences that contribute in rework arise are design errors, which have been found to create unsafe environments and may result in fatalities (Ortega & Bisgaard, 2000); (Rogge, Cogliser, Alaman, & McCormack, 2001); (Love & Edwards, 2004); (Robinson-Fayek, Dissanayake, & Campero, 2003); (Palaneeswaran, Love, Kumaraswamy, & Ng, 2008).

Errors dominate the cause of accidents and it has been revealed gross errors cause 80% to 90% in civil engineering projects (Matousek and Schneider, 1976).

(Burati, 1992) found that 79% of rework costs that arose in industrial engineering projects were due to design changes, errors and omissions. Similarly, (Love P. , 2002) revealed that design change orders that result in rework can account for as much as 50% of project's cost overrun. The costs of rework have been found to range from 5 to 20% of contract value (Barber, Sheath, Tomkins, & Graves, 2000); (Love & Edwards, 2004).

Another major cause of rework that has been suggested is uncertainty. This phenomenon comes from poor information, which often is missing, unreliable, inaccurate, and conflicting. Uncertainty is a consequence of numerous interrelated factors and not solely information. Therefore, to reduce rework we must identify what its causes are, then understand how these causes are interrelated between each others. Varying levels of risk and uncertainty can affect decision-makers choices during the onset of a project.

In the absence of risk and uncertainty knowledge, decisions taken prior to, or during construction may be erroneous and disastrous consequences ensue. Knowing and understanding rework causes can provide the basis to stimulate learning within the project environment. Not addressing the main causes of rework correctly can lead to an inherent uncertainty that prevails in the projects and can result in planning being problematic, especially when information is unavailable.

Faced with high uncertainty, the project team tend to rely on scope changes to solve problems as they arise during construction. Once changes arise they may be deemed to be ambiguous, erroneous and invariably require more rework.

The errors mentioned before are the main causes of accidents and has shown that large errors cause between 80 and 90% of the structural failures of buildings, bridges and other civil engineering works. (Matousek & Schneider, 1976). To improve quality and avoid rework it's necessary to understand the root causes of rework, that is, the basic reason for its existence or set of conditions that stimulate its occurrence in a process.

Other factor that leads into rework arise is poor rates of progress. This circumstances occur when staff involved with tasks either leave (staff turnover) or become unavailable and replacement staff are needed to complete the tasks (Love, Goh, & Han, "Rework in complex offshore projects: The case of oil and gas tension leg platforms", 2010). This problem may be further compounded by the prevailing skills shortage of workers (Love, Goh, & Han, "Rework in complex offshore projects: The case of oil and gas tension leg platforms", 2010). Discontinuity of design staff significantly impacts upon design process performance (G. Rodriguez & M. Williams, 1998).

The underlying root cause in this situation is that the inherent project knowledge held by each staff member cannot be seamlessly passed directly from one individual to the next, even if a handover "transient" period, and/or de-briefing process takes place.

Even staff recruited from the same organization cannot acquire sufficiently detailed project knowledge immediately after commencing work on site.

Already mentioned the various causes that can cause rework, (Love P. , 2002) brings a guide to classify incidences in three major branches. The author suggest that the main categories to group incidences are project, organization and human. This three major categories can harbor all incidences or non conformities that contribute in increasing rework inside any given project.

- The error in the project field are related to technical aspects, specifically during the design phase where all details and previous studies are lined up to conceive the very basis of the project.

- The errors in the organization field are related to management and supervision aspects. It is more about the flaws on tracing the project during the construction phase.
- The errors in the human field cover every mistake that happens due to direct intervention of the human factor in every aspect.

Another author with a similar point of view in this matter is Pei-Yin Feng. The author (Pei-Yin Feng, 2009) states that many sources of rework have been identified in the construction industry. The "cause and effect" diagram shown on Fig. 2.4 lay out the five main causes of rework in the construction phase of a project, which are:

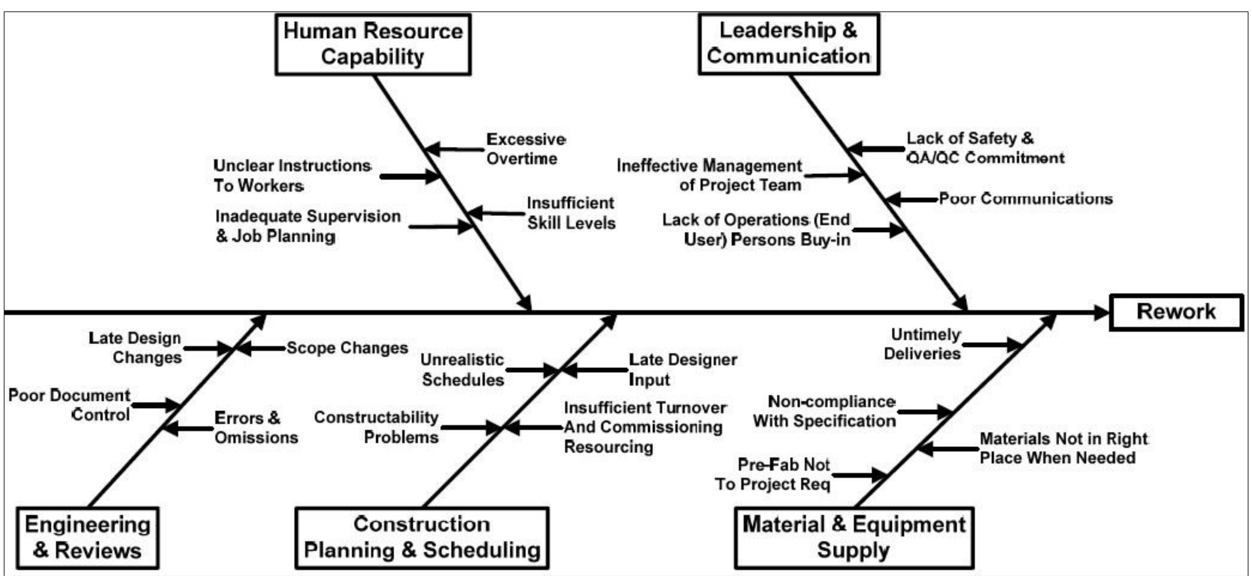

Fig. 2.4: Main causes of rework arise in construction projects.

1. Human resource capability: categorizes rework that deals with the capabilities of the engineers, contractors, and subcontractors that are involved with the project. Untrained personnel working on a facility can lead to rework.

2. Leadership and communication includes the management of the project team and information flow to and from the field workers. Also included is how the project will be checked for quality.

3. Engineering and review has four subcategories of poor document control, errors and omissions, late design changes, and scope changes. This category deals with the causes of rework that pertain to the decision making and flow of information within the discipline engineers and the owner.

4. Construction planning and scheduling categorizes rework within the construction project management phase of the process. The facility is in the construction phase and inappropriate processes are categorized in this rework cause.
5. Material and equipment supply categorizes rework that applies to the physical items that make up the project. It includes incorrect ordering and incorrect timing of when materials are to be received at the project site.

On another hand, (Hirano & Shimbun, 1989) statements are based in the idea of driving out errors in the design phase, which improves construction phase productivity, and according to the author, there are 10 categories of errors, which are:

1. Forgetfulness errors occur when the operator is not concentrating on the task at hand.

2. Errors due to misunderstanding occur when a person makes a wrong conclusion without knowing all of the required information.

3. Errors in identification occur when a decision is made without seeing the entire situation at hand.

4. Errors made by amateurs occur through the lack of experience.

5. Willful errors occur when an individual decides to ignore the rules under certain circumstances.

6. Inadvertent errors occur when a mistake is made without knowing how they occurred.

7. Errors due to slowness occur when actions are slowed down by delays in judgment.

8. Errors due to lack of standards occur when no clear instructions on how to accomplish the task at hand exist.

9. Surprise errors occur when items perform in an unexpected manner or outside operating parameters.

10. Intentional errors occur when people make mistakes on purpose to sabotage the process or product.

This is only one such list of categories, although many more exist. But in the end, most of the incidences, if not all in general, can be prevented if time is taken to identify, investigate, correct, and learn from errors.

At the end, all different statements converge in a single point, there are three main categories that could encompass all kind of causes that lead into rework, the human factor, the management of the project and finally the organization of it. Having seen these different approaches, the ideas and methods from author Peter ED Love are going to be used to lay down the different incidences that eventually leaded into rework arise. His methodology of classifying incidences according to Project, Organization and Human factors fit the best to describe the situation in which "The Club Residence" project was.

2.4. Post-mortem: means to identify rework

After a project is finished, learning about what went wrong in each stage through reviewing and analyzing the rate of success vs. failure accomplished. This process is highly encouraged to be fulfilled by any organization, so they can learn from their mistakes and in the next project, avoid to repeat them.

The truth is not as near as expected. In terms of (Williams T. , Eden, Ackermann, & Howick, 2001), it is the reality that the process of learning through feedback is not implemented. Frequently this is because the next bid and the next project are pressing and too urgent to leave time to reflect. Often it is because there are no standard methods in place for analyzing projects.

Even when post-project reviews are performed, there are no standard, structured, routine ways of analyzing projects to ensure that the organization can draw lessons and learn for future projects. If companies have not found them to be helpful or useful, then there is no motivation to carry them out for currently completing projects.

The task of data collection on what happened is a real deal, but is not always the main problem. It is gaining understanding about what went wrong (or right) and why using the compiled information in hand. It is a truly hard work to sort through all the "messiness" of information to really understand and trace what really happened during the project life and how it evolved.

In this kind of situations, the authors (Williams T. , Eden, Ackermann, & Howick, 2001), recommend mapping out the structure of causality. This process is essential to understanding the behavior of the project.

The goal in here is capture the facts and the causality underlying the facts, enable the stories of the project to be captured. Most of the valuable learning about past projects often comes from listening to those persons that assume the position of storyteller that were living part of the project.

In this way, combining objective project documentation with subjective perceptions about a project is the leap between historical data and historical information, this process helps capture these abstract perceptions in a structured format, to ensure coherence in data, and to allow to have a holistic perspective.

Furthermore, the natural transition into quantitative simulation allows those lessons to be established quantitatively, and place alternative scenarios and situations of the case "what if we'd done this…what if the promoter had done that" explored.

To put together all the ideas and conceive the mapping, the process is laid down into these steps, according to (Williams T. , Eden, Ackermann, & Howick, 2001); (Wiliams, Ackermann, & Eden, 2000):

1. Cognitive mapping is used to interview managers and capture the explanations given for the various circumstances of the project, and also to capture existing relevant project documentation. This technique structures the way in which humans construe and make sense of their experiences. Using special computer software is used to record and analyze the extensive maps developed.

2. Each person's cognitive map is input, and in the second stage these are then combined through cross relationships and the merging of identical ideas into a single "cause-map" which gives a holistic representation of the project's life. This model is developed and validated, including researching and further exploring conflicting or ambiguous parts of the map. This is a key stage of the process, and requires sophisticated facilitation skills.

3. Formal analysis of the cause-map, using analysis methods is then used to identify the feedback loops and the initial causes of the feedback loop which form the basis of understanding delay and disruption as it is generated by the dynamic impact of events. Reduction of these concepts to the foundations in the third stage leads to a reduced and simpler map. The overall structure of loops may still be complicated, but of course this is also true of the dynamics of the real situation: the overall behavior of interconnected feedback loops can be difficult to discern subjectively, and produce can be seen as a chaotic situation.

4. In order to quantify the information processed, the qualitative model must be able to be transformed into a quantifiable model. A quantitative analysis technique that could be argued to naturally follow on from the use of cause mapping and feedback is a simulation technique known as "System Dynamics" (SD), a technique that can indeed display the counterintuitive nature of complex projects linking "hard" or quantitative data with "softer" or intuitive data.

It has been argued that the use of a simulation methodologies can help overcome problems in perceiving feedback and offer a framework for conceptualizing complex scenarios that evolve in time (Williams T. , Eden, Ackermann, & Howick, 2001).

This is important because the post-mortem information not always offers an understanding insight of the project. In particular, counter-intuitive effects such as feedback and the compounding of individual effects are difficult to comprehend, let alone predict, intuitively. It is necessary to take a systems perspective of the project and what happened, and systems-modeling can help to demonstrate such effects

With these powerful tools, not only simple scenarios should be modeled, but also and specially complex scenarios, where the interconnections between cause and effect is not easy to observe and simulate more not-so intuitive behaviors in more radical scenarios to test our capacity so we can apply these new lessons in future projects.

2.5. System Dynamics

In real life, the ability to deliver a project on time and under the programmed budget has gotten a very difficult duty to accomplish. Life itself is a continuity of events on a dynamic space of time. This means that traditional approach tends to assume that if each element of the project can be understood then the whole project may be controlled. However, experience suggests that the interrelationships between the project's components are more complex than is suggested by the traditional work breakdown structure of project network (Rodrigues & Bowers, 1996).

An alternative view of the project is offered by System Dynamics which concentrates on offering a holistic view of the whole project. The approach emphasizes the interrelationships that may be responsible for unexpected overrun and overspend.

System dynamics is an appropriate modeling technique for analyzing or managing complex processes, which involve changes over time and are dependent on the feedback, transmission, and receipt of information (Love, Edwards, & Irani, 2008). System dynamics is defined as a rigorous method for qualitative description, exploration, and analysis of complex systems in terms of their processes, information, organizational boundaries, and strategies; which facilitates quantitative simulation modeling and analysis for the design of system structure and behavior (Wolstenholme, 1990).

This technique also offers a rigorous method for the description, exploration, and analysis of complex project systems comprised of organizational elements, the project work packages and environmental influences" (Rodrigues & Bowers, 1996). The method is compatible to use as a project post-mortem diagnosis tool (Cooper, 1980)**;** (Williams T. , Eden, Ackermann, & Tait, 1995).

Consequently, it can be used to provide managers with the necessary insights about the interdependencies and behavior between key variables that can contribute to rework so that learning and process improvements can be made to future projects (Cooper, 1993); (Love, Edwards, & Irani, 2008).

System dynamics has its own paradigm and has established itself as a powerful methodology (Mohapatra & Mandal, 1989). The modeling process is iterative, though the stages to be followed may appear to be sequential. Implicitly (Mohapatra, Mandal, & Bora, 1994) suggest that system dynamics can fulfill certain modeling requirements, especially in the context of rework. These include a holistic view of the rework phenomena, construction of causal relationships, identification of feedback mechanisms, and searching for explanations in behavior (Rodrigues & Bowers, 1996); (Williams T. , Eden, Ackerman, & Tait, 1996).

The primary focus in system dynamics is the examination of the effect that one element has on another. System dynamics as a modeling tool can be used to identify variables that need to be improved so that rework can be reduced or eliminated of any kind of project (Rodrigues & Bowers, 1996); Williams et al., 1996).

The System Dynamics (SD) methodology is typically used in long-term, strategic models and assumes a high level of aggregation of the objects being modeled. People, products, events, and other discrete items are represented in SD models by their quantities so they lose any individual properties, histories or dynamics. If this level of abstraction is very high in the project of study, it's use is appropriate to solve the problem (Sterman J. D., 2000). A system dynamic model can be approached through the interaction and complementing of different tools and techniques. The most relevant in matter are the rework cycle, which is explained using the causal-loop model, and also the stock and flow diagram.

2.5.1. Rework cycle

Rework cycle is fundamental to understanding project behavior (Williams T. , 2002). As seen in Fig. 2.5, rework cycle based on Cooper's model (Cooper, 1993) explains how as the work rate is determined by staff productivity and availability, and as project time advances, the amount of work remaining reduces. The quality of work produced may not be to the required standard and errors may occur. Errors are often not immediately identifiable and only transpire after a period of incubation in the system (Busby & Hughes, 2004).

After sometime these errors are detected and rework is identified which increases the amount of work to be undertaken by staff (Cooper, 1993); (Rodrigues & Bowers, 1996) (G. Rodriguez & M. Williams, 1998). The degree of rework required is dependent on how long the error has remained undetected. (Love, Goh, & Han, 2010).

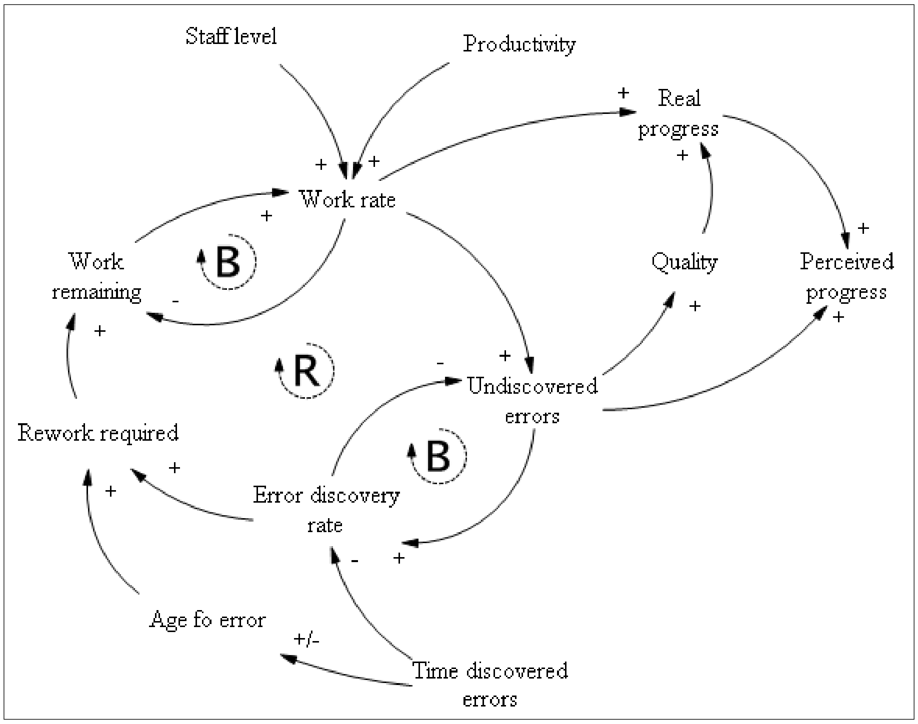

Fig. 2.5: Cooper's rework Cycle.

If the error needs a major change be undertaken, then all the perceived progress prior to the error occurring may be considered wasted. Addressing the error may generate more work for individuals and the possibility of more errors being generated. This is denoted by a reinforcing loop in the model, indicated by R.

However, the balancing loops, denoted by B, should counteract the accumulation of work remaining. The gap between perceived and actual progress may be difficult to close; it may appear that all work is nearly complete but the project can persistently remain at 90% completion (Abdel-Hamid, 1988); (Rodrigues & Bowers, 1996); (G. Rodriguez & M. Williams, 1998)

During rework cycle (Lyneis, G. Cooper, & A. Elsa, 2001), there are three major structures underlying the dynamics of a project, these are:

1. The work accomplishment structure, now referred to as the ‘‘rework cycle’’;
2. Feedback effects on productivity and work quality;
3. Knock-on effects from upstream phases to downstream phases.

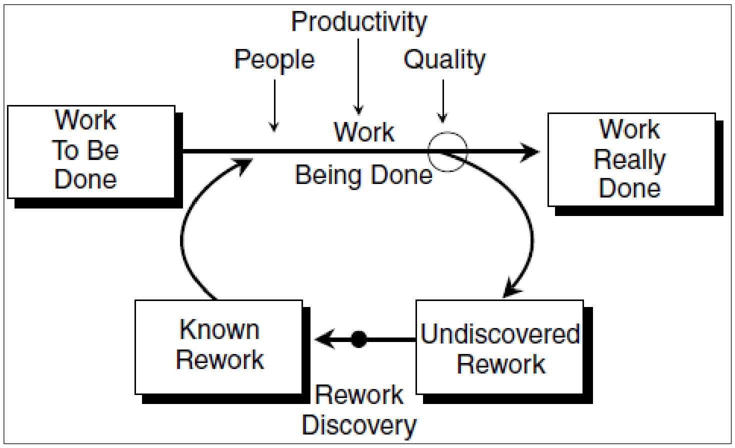

Fig. 2.6: Rework's work-stock division.

As explained in Fig. 2.6, rework cycle consists of four stocks of work. At the start of a project or project stage, all work resides in the stock "Work To Be Done". As the project progresses, changing levels of staff (People) working at varying rates of productivity determine the pace of "Work Being Done". "Work Being Done" initially depletes the stock of "Work to be Done", and later the stock of "Known Rework". Work is executed at varying, but usually less than perfect.

The quality factor represents the fraction of the work being done at any point in time that will enter the stock "Work Really Done" and which will never need re-doing. The rest will subsequently need some rework and flows to the stock of "Undiscovered Rework", work that contains as yet undetected errors.

Errors are detected in the normal course of work and as the result of downstream efforts or testing; Rework discovery may occur months or even years after the rework was created, during which time dependent work has incorporated these errors or technical derivations thereof. Once discovered, the stock "Known Rework" demands the application of resources beyond those needed for executing remaining "Work to be Done".

Rework is executed at the productivity and quality levels then prevailing, although the inherent level of effort required for rework may be more or less than that for initial work. Some re-worked items will flow through the rework cycle one or more subsequent times until they're completely done.

In a real scenario, activities are executed at varying levels, depending upon the individual's skill and competence, and as a result, quality can be compromised. The quality and the error discovery rate are the most important factors that should be considered. Bolstering a project with additional resources does not automatically resolve fundamental problems; a more incisive approach should be to reduce the number of errors or at least the time taken over their detection.

2.5.2. Causal Loop Modeling

Inside the system dynamics we can observe the relationship among all parameters involved through "Causal loop modeling". This is a technique used within the System Dynamics methodology to construct models of real world issues. Such models have been used to address an array of problems such as delay and dispute causation, litigation, error causation, the impact of change orders and rework, and contract design

A causal loop diagram seeks to highlight the feedback and complex interactions between variables, where root causes are often indiscernible. It can be used to model the influence of inputs on outputs and vice versa (Love, Mandal, & Li., 1999).

As seen on Fig. 2.7, a positive link (arrow with a "+") indicates that if the cause increases, the effect increases above what it would otherwise have been, and if the cause decreases, the effect decreases below what it would otherwise have been. A negative link (arrow with a "-") indicates that if the cause increases, the effect decreases below what it would otherwise have been, and if the cause decreases, the effect increases above what it would otherwise have been.

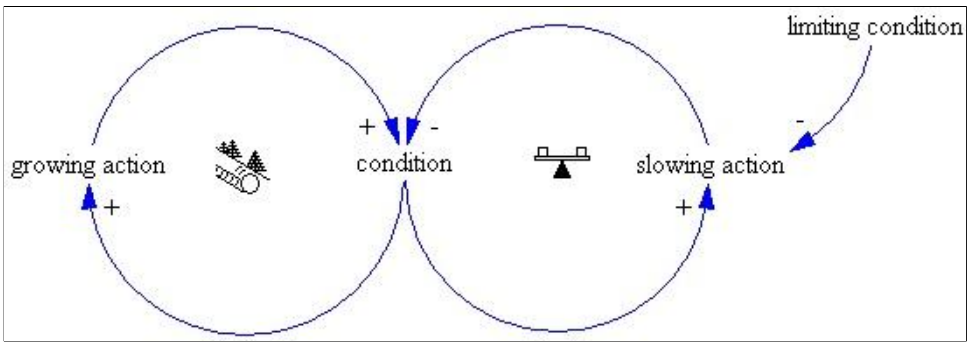

Fig. 2.7: Example of causal loop modeling within System Dynamics.

A causal loop diagram can show explicitly the direction and type of causality among the major factors, which is fundamental in understanding rework in a project system. It can be used to model the influences of inputs on outputs and vice-versa. (If variable "A" is causing a change in variable "B", the direction of causality is from "A" to "B". If an increase (decrease) in variable "A" leads to increase (decrease) in variable "B" then the type of causality is positive. (Love, Mandal, & Li., 1999).

It is also imperative to know the difference between "correlation" and "causality" to truly understand and idealize a functioning causal loop model.

- Correlation is a statistical relationship between two or several variables.
- Causality: is a relationship between an event (the cause) and a second event (the effect) where the second event is a consequence of the first.

Knowing the meaning of each concept allow us to identify which events causes each problem and the correlation between all the elements in the model, if it exist. Correlation does not necessarily implies causality.

System Dynamics can be seen and used as a method of perspective and set of conceptual tools that enable us to understand the structure and dynamics of complex systems. It is also a rigorous modeling method that enables us to build formal computer simulations of complex systems and use them to design more effective guidelines and organizations.

Together, these tools allow us to create management simulators where space and time can be compressed and slowed so we can experience the long-term side effects of decisions, speed learning, develop our understanding of complex systems, and design adequate strategies for greater success and minimizing any source of rework.

2.5.3. Stock and flow diagrams

Although causal loop diagrams aid in visualizing a system's structure and behavior and helps analyzing the system qualitatively, to perform a more detailed quantitative analysis, a causal loop diagram is transformed to a stock and flow diagram. A Stock and flow model helps studying and analyzing the system in a quantitative way, such models are usually built and simulated using computer software. This diagram consist of the following items (Bellinger, 2009):

A stock is merely a bucket into which something can accumulate or be withdrawn from. What the bucket holds is specific to the model in question. The modeler can set an initial value or level for the stock that it will take on at the start of the simulation. The initial value may be a simple number or a more complex mathematical expression.

A flow transports a material from one stock to another. The designer must enter the rate of the flow by specifying both the magnitude of the flow and the time period over which that magnitude operates. Flows may connect two stocks together and, alternatively, can lack a start or an end. As with the initial value of a stock, the rate of a flow can be a simple number or a more complex equation. The equation can be based on many factors including the values of the stocks the flow is connected to and the current time.

A variable is a pre-calculated or dynamically calculated value that can be useful to synthesize data or supply calibration values to the model. Variables can also be used to create forcing functions which are based on the current time. Generally stocks should only be used to model items that have inflows or outflows. If there are stocks in the model without either an inflow or an outflow, it would almost certainly be modeled better with a variable.

Finally, all these elements mentioned before need a connection that can relate them and give sense and unity to the model in a holistic way. The tool needed to accomplish this is a link. This item makes two objects (flows, stocks, converters, or parameters) aware of each other and reference the value of each other in their equations. If two stocks, or variables are not connected by a link, it will be impossible to reference the value of the first in the equations of the second or vice versa.

2.5.4. System dynamics software availability

Nowadays, there are several software options on the market when choosing a tool for modeling and simulation using system dynamics. These software have more or less the same features, but even so, there are specific differences between each others. On the list next ahead, will be presented some of System Dynamics software tools to compare their features and select one that meets the needs of the project. First, all software are going to be grouped in two categories, commercial versions and free versions:

Commercial versions (non-free software) are:

- Analytica: it's a non-free commercial software based on C++ programming language that supports system dynamics, Monte Carlo simulation, array abstraction, linear and non-linear optimization. Uses influence diagrams to define, navigate, and document models. It was last updated on 2013. Pros: recent update, multiple options to work. Cons: paid license for use, complex interface, not free 30 day trial.

- AnyLogic: a non-free commercial software based on Java, it supports system dynamics, agent based and discrete event modeling. It was last updated on 2012. Pros: multiple options to work. Cons: paid license for use, outdated version complex interface, tools not needed to develop case study model, not free 30 day trial.

- Consideo: commercial software with capabilities of combining different methods, concept maps, system dynamics. Last updated on 2012. Cons: Poor information available, paid license, not free 30 day trial.

- Dynaplan Smia: commercial software based on C++ language that can model System dynamics, causal loops, multi-dimensional arrays, hierarchical models, reusable components, scripted functions, stochastic and sensitivity analysis, optimization, scenarios. Last update was on 2013. Pros: Recently updated, different tools to model SD conceptual maps. Cons: paid program, needs to download software, complex interface with user.

- Forio simulations: a commercial web-based system dynamics software. Cons: No much information available of this product or if is still on the market, paid license.

- MapleSim: non-free commercial software based on Java and Maple language. It features Modelica-based system-level modeling tool. Leverages symbolic computation through tight integration with Maple computer programming. Last update on 2013. Pros: recent interface, powerful tools provided to create solid models. Cons: paid license, no free trial to try out the software, Modelica system language not well known.

- Powesim Studio: One of the most solid commercial software. Has a 30 day free trial based on C++. Supports system dynamics and discrete event modeling. Free renewable license for Studio Express. Last update on 2013. Pros: solid software with powerful tools to create models, strong support from website, several tutorials to explain its use, free trial to experience the program. Cons: Expensive program to buy.

- Smile: commercial software based on C++ programming language featuring System Dynamics software with object-based concepts: hierarchical (nested) models, associations between models. Models may be "pure" System Dynamics. Discrete event-based modeling. Free evaluation license limited to 25 model elements not by time or functionality.

- Stella iThink: also another of most solid commercial software's in the market It features Model builder based around an intuitive icon-based graphical interface. There is a free month trial and student versions with reduced price. Last update on 2012. Pros: solid software with powerful tools to create models, strong support from website, several tutorials to explain its use, free trial to experience the program, recently updated. Cons: Expensive program to buy.

Open-source versions (free software) are:

- Ascend: it's a free GPL software based on open source computer program that can solve small to very large mathematical models. ASCEND can solve systems of non-linear equations, linear and nonlinear optimization problems, and dynamic systems expressed in the form of differential/algebraic equations. Last update was on 2012. Free software, non linear equation solver included. Slightly outdated. Cons: complex interface with user, no information or guides on how to use this program.

- Insight maker: it's a free software based on java script. Doesn't need to download any software, only a web browser and internet connection. Features multi-user, supports causal loop diagrams, rich Pictures, dialogue mapping, mind mapping, as well as stock & flow simulation models. Also has embedded a complete manual and several examples on how to use this powerful tool. Last update on 2013. Pros: free software, available just by having internet browser, user doesn't need to download any software to computer, several tutorials and examples about learning to use this tool, recently updated, user friendly interface to create models right away. Cons: Medium difficulty to learn how to program the model so simulation can run without problems.

- JDynSim: also another free software based on Java. This tool can hold system dynamics framework from Java. Last update on 2010. No further information. Pros: free software. Cons: software outdated, no information available nor manuals or tutorials to learn how to use it.

- NetLogo: free software agent-based on GPLv2, java and Scala language that supports modeling environment in LOGO; supports system dynamics models as a secondary feature. Last update on 2009. Pros: free software. Cons: software outdated, no information available nor manuals or tutorials to learn how to use it.

- Pyndamics: free software based on Python language with MIT licencse. This tool features free and open source numerical dynamics software written in Python, supporting a simple syntax for writing differential equations. Last update on 2013. Pros: recently updated, free software powerful tools provided to create solid models. Cons: complex interface, user needs good programming skills to run model.

- Simantics System Dynamics: free open source download software. This tool is based on Java and Modelica language, and features system dynamics modeling software with stock and flow modeling, hierarchical models and array variables. Last update on 2013. Pros: recently updated, free software powerful tools provided to create solid models. Cons: complex interface to use the program, user needs good programming skills to use the software.

- TRUE (Temporal Reasoning Universal Elaboration): free software based on WLanguage Windey Fetures system dynamics + 3D Modeler Rendering using OpenGL graphics library + Procedural animation. It was last updated on 2014. Pros: Recently updated, free open source software, powerful tools to create any kind of model, 3D modeling support. Cons: complex interface on how to use the software.

Once comparing all options mentioned in previous listed, the software Insight Maker is going to be the eligible choice to develop this case study. The main reason is that is a tool that doesn't need any downloads and it can be accessed anywhere just by using a web browser and signing in to one's account. Also, their website has plenty of information, tutorials, example from other users that helps developing our own model.

After reading the manual and tutorials available and seeing several examples developed by the author of the website, Gene Belinger, one can appreciate how intuitive and user-friendly is the interface. Also, as a free software, it is available to start using it immediately. For these reasons exposed, the program "Insight Maker" is going to be used in this Case Study as a simulation tool.

2.6. Description of Dominican Republic situation

The Dominican Republic has the ninth largest economy in Latin America and the second largest economy in the Caribbean and Central American region. Though long known for sugar production, the economy is now dominated by services, tourism and just to 2009, construction sector. The country's economic progress is exemplified by its advanced telecommunication system.

Nevertheless, unemployment, government corruption and inconsistent electric service remain major Dominican problems. The country also has "marked income inequality". International migration affects the Dominican Republic greatly, as it receives and sends large flows of migrants. Haitian immigration and the integration of Dominicans of Haitian descent are major issues. A large Dominican emigrants exists, most of it in the United States. They aid national development as they send billions of dollars to their families, accounting for one-tenth of the Dominican GDP.

2.6.1. Weather

The climate of the Dominican Republic is mostly tropical. The annual average temperature is 25 °C. At higher elevations, the temperature averages 18 °C while near sea level the average temperature is 28 °C. Low temperatures of 0 °C are possible in the mountains while high temperatures of 40 °C are possible in protected valleys. January and February are the coolest months of the year, while August is the hottest month (Library of Congress, 2007).

The rain season along the northern coast lasts from November through January. Elsewhere, the wet season stretches from May through November, with May being the wettest month. Average annual rainfall is 1,500 mm (59.1 in) countrywide, with individual locations in the Valle de Neyba seeing averages as low as 350 mm (13.8 in) while the Cordillera Oriental averages 2,740 mm (107.9 in). The driest part of the country lies in the west. Tropical cyclones strike the country every couple of years, with 65% of the impacts along the southern coast. Hurricanes are most likely between June 1st until November 30th (Library of Congress, 2007).

2.6.2. Country's economical situation

The Dominican Republic has one of the largest, but no so stable economy in Central America and the Caribbean (Department of State, 2012). It is an upper middle-income developing-country, with a GDP per capita of $5,736.44 million (on 2012) and a GDP growth rate of 3.9% annually. In Latin America it is considered to be high. Growth in GDP was led by imports, followed by exports, with finance and foreign investment the next largest factors (D.L., 2007)

Also, the country is primarily dependent on natural resources and government services. Although the service sector has recently overtaken agriculture as the leading employer of Dominicans, agriculture remains the most important sector in terms of domestic consumption, and is in second place, after mining, in terms of export earnings. The service sector in general has experienced growth in recent years, as has construction. Free Trade Zone earnings and tourism are the fastest-growing export sectors (Hoy, 2007).

Economic growth takes place in spite of a chronic energy shortage, which causes frequent blackouts and very high prices on electric supply. Despite a widening merchandise trade deficit, tourism earnings and remittances have helped build foreign exchange reserves. The Dominican Republic is current on foreign private debt.

Following economic turmoil in the late 1980s and 1990, during which the gross domestic product (GDP) fell by up to 5% and consumer price inflation reached an unprecedented 100%, the Dominican Republic entered a period of growth and declining inflation until 2002, after which the economy entered into a full recession (Department of State, 2012).

This recession followed the collapse of the second-largest commercial bank in the country, Baninter, linked to a major incident of fraud valued at $3.5 billion. The Baninter fraud had a devastating effect on the Dominican economy, with GDP dropping by 1% in 2003 as inflation ballooned by over 27%. All defendants, including the star of the trial, Ramon Baez Figueroa, were convicted.

According to the 2005 Annual Report of the United Nations Subcommittee on Human Development in the Dominican Republic, the country is ranked No. 71 in the world for resource availability, No. 79 for human development, and No. 14 in the world for resource mismanagement. On the Corruption Perception Index list of 2012, the country was ranked on 118 out of 174 of most corrupted government administration. These statistics emphasize national government corruption, foreign economic interference in the country, and the rift between the rich and poor.

2.6.3. Currency

The Dominican peso (DOP, or RD$) is the national currency, although United States dollars (USD) and Euros (EUR) are also accepted at most tourist sites. The dollar is implicated in almost all commercial transactions of the Dominican Republic; such dollarization is common in high inflation economies. Americans traveling to the Dominican Republic have a very good exchange rate.

The exchange rate to the U.S. dollar, liberalized by 1985, stood at 2.70 pesos per dollar in August 1986, 14.00 pesos in 1993, and 16.00 pesos in 2000. Having jumped to 53.00 pesos per dollar in 2003, the rate was back down to around 31.00 pesos per dollar in 2004 In present, as of September 2013 the Dollar rate was 42.70 pesos per dollar, and the Euro rate was 58.50 pesos per Euro according to the Central Bank of Dominican Republic.

2.7. Construction industry characteristics in Dominican Republic

The construction industry has been key to the country's economic development, especially in recent years due to their highly dynamic, and constitutes one of the most important and the greatest impact for their close links with the creation of basic infrastructure as bridges, roads, ports, railways and energy production plants.

Construction sector is also one of the main economic axis and one of the most versatile and dynamic of Dominican production engine. Around 2009, this sector produced RD$92,737 MM (US$2,650 MM).

This amount is equivalent to a 5.9% of Dominican Republic GDP and generated approximately 300,000 direct work places; and indirectly generates almost a million work places, involving different social strata

Construction in general is known for majorly using masonry walls made of concrete blocks, usually used on economic houses. For higher buildings, structures consist mainly of reinforced concrete frames with non structural masonry walls and roofs composed by lightened slab systems.

With city modernization and population growth in last decades, Santo Domingo has experienced an important vertical growth. This is related to numerous apartment buildings of considerable height, in which a great part are founded in not so stable soils. In poor social classes, houses are constructed by the own members of the community, who lack of experience and formation to realize this task.

The diversity and dynamism of this sector can be observed on the multiplier effect that it has on the general economy of Dominican Republic. For this matters, the construction sector is used as an indicator of economic development. Due to these reasons, the Dominican State has promoted his expansion through the creation of institutions such as "Banco Nacional de la Vivienda" (BNV), focused on satisfying the demand of houses on middle-class strata. Also with the involvement of the Central Bank of Dominican Republic, several laws were applied to promote the reduction of mortgage interest rate.

According to the Dominican Construction House (Cámara Domininicana de la Construcción GADOCON), 65% of houses built in the country are elaborated with no legal registration and procedures, lack of property title and not approved blueprints and documentation. This is why Construction is mainly focused on meet housing demand in two important sectors:

- Urban
- Touristic

Urban sector in Santo Domingo is characterized for having a demand based on luxury apartment buildings in the most exclusive zones within the central city polygon. In order of importance, the 5 main cities where the 90% of house demand is focused are:

- Gran Santo Domingo
- Santiago de los Caballeros
- San Francisco de Macorís
- Baní
- La Romana

The first home housing demand, the urban sub-sector, is divided into three niches:

- High class: it is the 6% of total population. This sector is known for having a high acquisitive power and requires no bank funding. This class aims mainly to luxury apartments.

- Upper-middle class: demand in urban apartments, characterized by being able to access bank financing.

- Middle class, medium-low and low: this sector is affected by a million house deficit. Institutions like "Banco Nacional de la Vivienda" and "Instituto Nacional de la Vivienda" help funding housing projects for this middle and low class with short income. However, due to restrictions on bank funding for low class, this sector lacks of ways to access to credit funds, and so the State meets their demands.

In terms of production, construction sector produces around US$2,650 MM. Between 2003 and 2008 the industry grew more than 69% in its production capacity, boosting the country's economy. Around 65% of construction investment is applied in apartment buildings, 15% of investment goes to housing and hotels construction, and the remaining 15% belongs to government projects.

In conclusion, construction sector is a major driver of economic development in the Dominican Republic. There is a very close relationship between the behavior of this activity and the rest of the economy, so much so that it is used as an indicator of development

2.7.1. Contracting modalities used in Dominican Republic

Among the modalities for selecting contractors, are the following:

1. **Competitive Bidding:** procedure in which the contracting company invites individuals and other companies to participate in the submission of proposals for the execution of the work.

   The entity making the call, previously established characteristics of the good or service you are requesting, to which they must adjust those interested in participating in the tender. In this call, open to all those interested to consider that have the technical, managerial and financial to fully comply with the contract.

   The purpose is to get the best deal on quality and price of the contractors or suppliers. The choice of the contractor shall be made generally through public bidding.

2. **Direct contracting** or direct recruitment selection modality only proceed in the following cases :

   a) National emergency manifest.

   b) Contracting loans.

c) Inter-administrative contracts, always when obligations arising from these contracts are directly related to the object of the implementing entity mentioned in the law or its regulations. Exceptions are made to works contracts, supply and trust management and public fiduciary when public higher education institutions are the executors of the project.

d) Contracts for the development of scientific and technological activities.

e) When there is no plurality of bidders in the market.

f) To provide professional services and management support, or for the execution of works of art that can only be entrusted to certain individuals.

g) Lease or purchase of real estate.

3. **Brief Selection:** Corresponds to the expected objective selection method for those cases where the characteristics of the object of the contract , the circumstances of the employment or the amount or destination of the goods, works or service may preempt streamlined processes to ensure efficient contract management .

   Selection is objective in which the choice is made by offering more favorable to the institution and the purposes for which it seeks, without considering factors of affection or interest and generally any kind of subjective motivation . The award rests with the bidder who submitted the offer with the best cost - benefit. The contract will be signed by the total price offered.

A common practice in this type of contract is trying to get extra work , as these can be traded at a price more favorable than initially agreed . This finding leads to changes in the execution , either in materials, design optimization , as well as increasing amounts on games with favorable prices and the decline in those with unfavorable prices.

2.7.2. Major construction regulatory institutions

In Dominican Republic there are several institutions and organizations in charge of assure construction and residential developing sector in the country ranging government agencies to banks and professional organizations. Their main objective is to ensure that public housing buildings are under a level of quality that ensures smooth operation and meets the needs of end users. These institutions are related to issuing the necessary regulations and permits for the proper development of the project mentioned in this case study.

2.7.2.1. Banco Nacional de Fomento de la Vivienda y la Producción (BNV)

"Banco Nacional de Fomento de la Vivienda y la Producción" is an entity of mixed public-private investment fund, converted to multiple sectors development bank, which provide resources in short, medium and long term instruments. This institution promote financial and capital markets, facilities which will influence the credit policy and financing of productive activities in the country in order to improve business competitiveness.

As a diversified development banks it has the legal and institutional mechanisms which allows the relevant actions to fulfill the promoting modality effectively, assisting with the provision of wholesale funds to productive sectors and housing in the country.

As a bank, it can channel financial resources to market through other regulated or unregulated financial institutions, thus complementing the supply of private resources that are available to the productive sectors of the nation.

The institution's primarily functions are:

- Promote and finance the construction, acquisition and upgrade homes and buildings for residential, commercial and institutional, as well as the urban development of land for residential purposes.

- Provide, either directly or through a subsidiary, service Insurance coverage Insured Mortgage Development (IMD) to all financial intermediaries to grant housing loans, and any other entity that provided that service. The Bank or the subsidiary entity may extend IMD insurance services to finance other mortgage operations.

- Promote the development of the capital market, in particular through a secondary mortgage market, encouraging the channeling of resources to that market and investment in it.

- Promote the development of the capital market, in particular through a secondary mortgage market, encouraging the channeling of resources to that market and investment in it.

2.7.2.2. Ministerio de Obras Públicas y Comunicaciones (MOPC)

This institution was with the sole purpose of managing and supervising that all construction works in the country are regulated and made under the permitted technical criteria, ensuring the safety of the structure and its users. (MOPC, 2005). The second most important purpose of this entity the Handling Office Plans, through which will be the review of plans for any building and/or structure of any kind verifying that all technical standards and specifications are met.

The institution's main functions related to the case study in question are:

- Set the rules and dangers of conditions and regulate Design and Construction of Works of Engineering and Architecture.
- Control the quality of building materials manufactured within and outside the country.
- Develop and implement regulations which should govern the construction activities in general.
- Plan, program execution and carry out socio-economic studies and technical buildings and road projects required to ensure the establishment of appropriate communication networks by land, air and sea around the country.
- Ensuring quality in the execution of engineering and architecture in the country, through analysis, evaluation and monitoring of plans, budgets works and technical quality of the personnel involved in the activity.
- Monitor and supervise public works implemented to ensure compliance with the rules and regulations established for construction activity, and that they comply with the specifications in the contract works.

2.7.2.3. Colegio Dominicano de ingenieros, arquitectos y agrimensores (CODIA)

This institution was created in 1963, first known as the Dominican College of Engineers and Architects. This institution is responsible for ensuring that all professionals working in the country are guaranteed by law to perform their duties as construction professionals through the emission of state accreditation known as the exequatur.

Their main objectives to accomplish are:

- Monitor the practice and safeguard the general interests of the professions that groups within it, and especially, for the dignity, rights, duties and improvement of its members.
- To serve as a guardian of the public interest and act as Advisor to the state in matters within its competence.
- To foster the establishment of legal technical standards, specifications and laws that should govern any stage of project development and execution of works as well as recruitment.

3. Chapter 3: Case Study

3.1. Description of the project

The project chosen as case study to develop this master thesis is "The Club Residence Collection, Guavaberry", Juan Dolio, Dominican Republic. The contract name was known as "The Residence Club Collection, Guavaberry: Phase 2 finishing and Phase 1 adequacy". The project was under direction and management of promoter company's "Nolan Group".

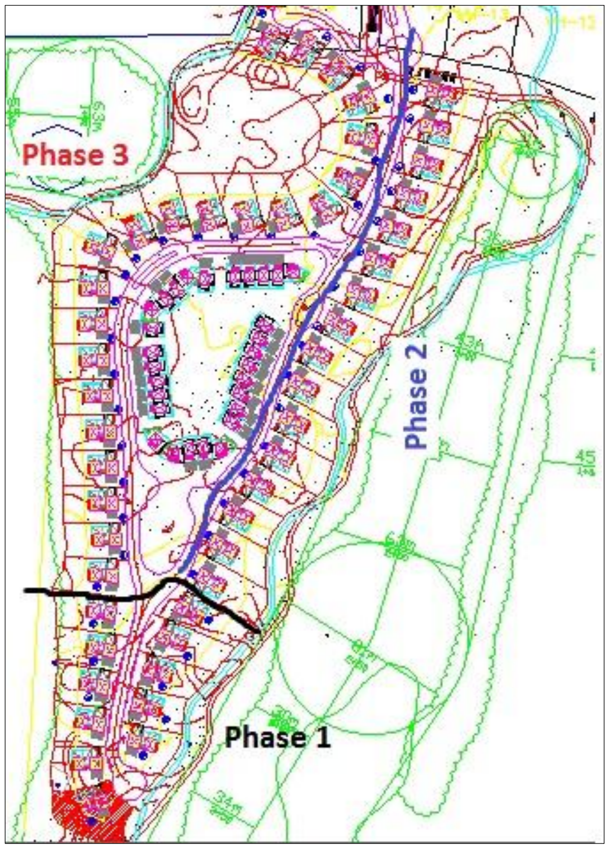

Fig. 3.1: Localization Map of "The Residence Club" and scheme of project's phases.

The project in its totality was divided into three phases, as seen on Fig. 3.2, which would be developed as the houses were being sold. This residential project initially was under a first contractor who developed and delivered a first group consisting of 10 houses. This first stage was known as "Phase One", completed and handed to final owners around 2009. Project design was made by the company GVA Dominicana, S.A., construction works responsibilities were under Civilmek, S.A and infrastructure works were in charge of Acosta-Moreta Ingenieros.

The original budget for the entire project was 168,924,006.73 $RD broken down as follows: the terrain plot size: 56,900 m^2 at a cost of 45,130,300.00 $RD. Phase One stage including the first 10 villas delivered was estimated in 65,247,854.47 RD$.

With sale's success on this first stage, promoter decided to start Phase 2 construction immediately with a different contractor, Lexco S.A., but soon after start, both parts entered into legal discussions about diversion of financial funds, low quality materials used on construction, contrary to that specified in the general budget, and slow work progress, despite the amounts of money disbursed at the time. These disagreements had cost the project a year of paralyzed works.

In august 2010, works resumed under new contractor named "Ingeniark", in which the author had the opportunity to be a part of the project. At the beginning, this company was present just as a consultant party to look into possibilities of redesigning the project, searching ways to reduce cost by the substitution of materials more durable while maintaining the eco-friendly environment of the project. Subsequently, as new project scope was approved gladly by the promoter, Grupo Nolan, Ingeniark became the new general Contractor, supervising all works done in site.

Phase 2 initial budget including 16 villas started around 74,293,108.73 RD$ with previous contractor, but the final budget ended in 77,522,724.17 RD$ including general design modifications. Time stated in contract to complete all works was 1 year and payments for works performed was based on unit price per task with bi-weekly scheduled payments. The delivery method used design-build methodology. The contract established that the most important goals to accomplish were to correct the problems and design problems in phase 1 houses and complete the construction stage of 16 houses that conformed Phase 2.

The main activities to execute were:

1. Conceive a reengineering process to adequate the phase 1 house design, introducing a new free-maintenance design by replacing specific materials that were not durable and compatible with sea environment.

2. Repair the defects that customers were complaining related to wrong design choices made by previous contractor.

3. Complete the construction stage of phase 2 houses, now including the upgrades in the free-maintenance design upgrade previously applied to phase 1 houses.

4. Design, manage and build phase 2 project's infrastructure to finish the entire phase.

Although the contract stated that the payment should be done under unit price, some specific task could not be measured so easily due to its nature. Therefore, these special tasks related to repairs and remodeling were arranged with the promoter by a cost plus a fee contract, in which the contractor made the respective repairs, and then presenting the detail of works done to the promoter, charging a fee for management and supervision.

The case study presented on this master thesis focuses mainly in three major aspects:

1. Identify all design and construction errors made by previous contractor on the houses already delivered to final owners.

2. Perform all repair duties related to design and construction errors, and also all nonconformities that owners were complaining about.

3. Apply all design changes into unfinished phase 2 house group to avoid repeating the same mistakes and complete construction task until delivering the house to owner

On phase 1 houses in need of repairs, there was a peculiarity in the way works were carried. It was not a normal construction process, because it must be considered that there were lots of incidences and errors to correct. The implementation of new measurements on the final product on phase 2 would contribute to prevent the promoter from suffering the disadvantages of all these corrections.

The costs associated with repairs carried out could not be considered normal and necessary repairs are so numerous that significantly impacted the final price of the finished home. Besides that, any savings from economies of scale was unfeasible and untimely.

It was important to consider that any changes or adaptation of materials that would apply to homes being repaired, would impact the houses that were still in under construction. This is why materials used in finishing details that were likely to run out or had a temporary existence in suppliers warehouses, were acquired by the total needed to finish all the work. This measure was in order to maintain uniformity in the final product of all households and not take the trouble of having to make last minute changes in certain products due to the exhaustion of their existence in the warehouses of the suppliers

However, despite the working environment and project's general progress, on December 2010, the entire project went in a total paralization due to promoter's insufficient funds to continue the progress of works. This event demoralized the entire job crew, as a big part couldn't receive their rightful payments for their work already done.

On March 2011, the project got back in its feet and restarted once again, but the work crew refused to start again without being paid for previous task completed before project's paralization and also they wanted to renegotiate work fees and update them to current situation. This led into a several weeks strike until all differences were settled.

After the strike was over, some workgroups didn't agree with contractor with resuming works in base of old prices negotiated at the beginning of the project. Work head groups tried to renegotiate unit price on several tasks with contractor.

As not reaching to an understanding, workers with experience and knowledge of the project quitted. This event caused a delay on final delivery date of houses because new staff had to be hired and trained until got used to project's rhythm.

It should be mentioned that during Phase 2 construction works ending, ideas were being conceived and discussed about starting Phase 3 design stage. Phase 3 would consist of a group of single house, with possibilities of being changed to duplex house due to sales optimization to maximize profits, but this part was never developed. For this matters, it's not going to be covered in this master thesis.

3.2. Project location

The project used as case study is located in the American continent, in the American continent, in the Caribbean Islands, specifically in La Española island, as shown on Fig. 3.2.

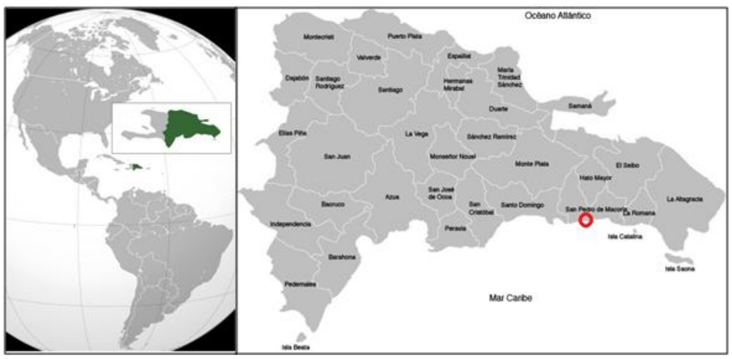

Fig. 3.2: Location of Dominican Republic within American Continent and work site location.

The job site, Guavaberry Golf Club, is a private residence community located in Juan Dolio, a county located in the outskirts of Santo Domingo, at a distance of 72 km at east. Work site location inside Dominican Republic is presented on Fig. 3.3.

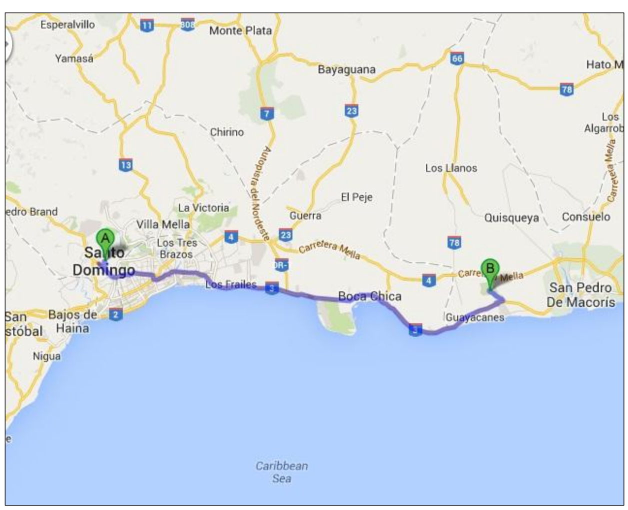

Fig. 3.3: Worksite location from Santo Domingo.

3.3. Work Control tools

3.3.1. Work logbook

On the first day works started, the management started a logbook in which the field engineer recorded daily events and happenings related to the development of the work, as well as any comments or suggestions that made the auditing, the quality inspectors, promoter, house owners, etc.

Also, every detail record that happened in front of work, such as weather, personnel working, and connection status of the equipment, work progress, advancement of environmental management measures, social actions, material supply, accidents, was written as well. At the end of each daily entry, date was stamped and signed by the field engineer.

3.3.2. Organization chart

Fig. 3.4 shows the general organization of the contract. The structure was led by the promoter, who had the power to give orders on any development and should provide solutions to the problems that arose. His figure visible was the president and general director of Nolan Group Company.

The contractor entity, on the other hand, was represented by the general contractor, who intermediated with subcontractors and workers. The figure of the general contractor was represented by the president of the company Ingeniark, its highest representative.

On site the field engineer was in charge of taking the necessary decisions on site who oversees work development and look to meet safety guidelines. Finally the foreman, who handled all personnel working in site, keep tracked of the work done, and made the payment to the employees biweekly, as stated in contract.

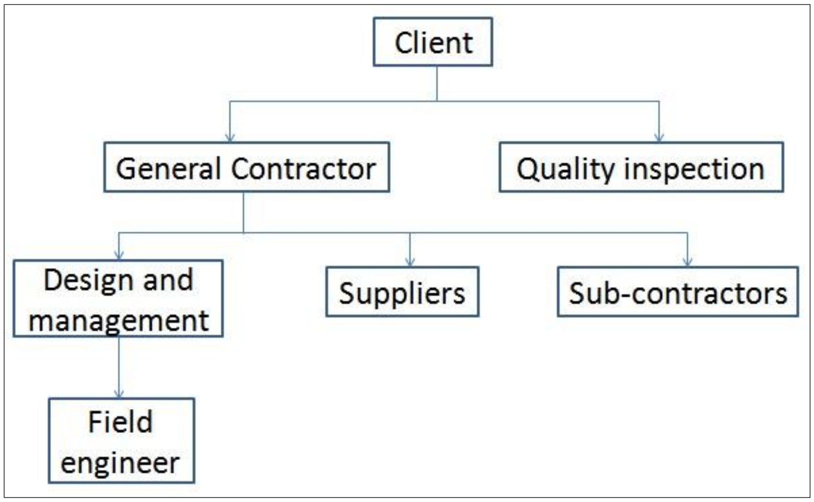

Fig. 3.4: Organization chart stated in contract.

All staff had the obligation to stay full time in site to ensure that the work would be done and conducted properly, and in the event there was an incident, it would be resolve it immediately.

The role played by the author of this master thesis within this case study was a resident of work by the contractor. Therefore, the interpretation and writing is done from this viewpoint. The analysis of the work and its implications will be trying to maintain an unbiased viewpoint.

3.3.3. Quality inspections and controls

The promoter exercised control and supervision of the execution of the contract work through a controller; a third party verify general compliance obligations incurred by the general contractor. The controller exercised comprehensive control over the project, for which, at any time, could require measures to the general contractor to maintain, during execution of the contract, the technical, economic and financial existence of works done.

The controller kept an eye on the contractor so the works would be started only when the respective permits, authorizations and concessions for the use and exploitation of resources were granted. The controller also watched that environmental statement were fulfilled at the time; and last, it was authorized to order the correction of incidences that were occurring in the shortest time possible while determining the mechanisms and procedures to anticipate or deal quickly and efficiently with disputes during the execution of the contract.

The contractor must comply with the orders, orally or written, imparted by controller. If, however, the general contractor did not agree, the controller should communicate in writing, prior to executing them. Otherwise, should be jointly liable with the auditor, if the fulfillment of those orders were derived into harm to the promoter.

The promoter, on the other hand, could at any time order the suspension of the work if there was a systematic failure of the instructions given by the controller without right to claim or soliciting time extension.

The main functions and powers of the Controller were:

- Collaborate with the Contractor to the success of the work.
- Require compliance with the specifications and the contract in its entirety.
- Study and recommend changes as deemed appropriate or necessary in specifications and submit for consideration by the promoter.
- Check the data of work quantities and approve payment orders prepared by the Contractor.

- Require the Contractor the use of trained technical personnel and duly registered in accordance with law and request the dismissal of that, in his opinion, be careless, incompetent, insubordinate, or whose work is detrimental to the interests of the promoter.

- Ensure compliance with safety standards.

- Ensure that the Contractor complies with the provisions as necessary and all the powers that the Auditor considered as facultative.

- To inform the Legal Office Department of promoters enterprise on any possible breach of contractual obligations by the contractor, which could result in proceedings for the imposition of fines and issue concepts and present information so asked for this.

- Inform the insurance company care about calls and non-compliance of the contractor.

- Meet the requirements of the specifications stipulated in the contract.

- Review and approve the Contractor's work program.

- Ensure that met the requirements of all applicable regulations and required for execution of the works.

The Contractor must perform the work in accordance with the instructions and orders given by the customer or the auditing. However, this does not lessen in any degree the responsibility or authority in the direction of the work.

In addition to the general features mentioned before, in order to seek the proper and timely execution of works, the controller supported, assisted and advised the Promoter on all matters of technical, financial, economic and legal questions are raised during the performance of the contract.

The contractor should provide the facilities required by the auditor to perform its work, providing office supplies, furniture and tools required for this purpose within the worksite perimeters, as well as those required for safety while performing their duties.

3.3.4. Quality self-check

The sub-contractors, the foreman and leaders of the different workshops were responsible for the quality of the outcome of their work. Therefore, it was their duty to check the status of their work under certain standards (clean finish on the final result and a clean environment around the worksite), so the general contractor would approve the work as done and include them in the upcoming payroll week.

After completion of parts of the work that were hidden, and before starting the subsequent task, subcontractors or workshop leader should inform to the field engineer to proceed to measure the built work . If not proceeded in this way , the general contractor could order in writing the discovery of the hidden parts , in order to exercise its control functions . In this case , who had done the job he was not entitled to the recognition of additional costs or extensions to the period of execution.

The general contractor could refuse to receive work, partially or totally performed, due to defects in materials or elements used. Although the samples and corresponding prototypes had been previously verified by the field engineer or quality inspectors, without prejudice to the specifications on the acceptance of defective supplies.

Any work that was rejected by defective materials or elements used in work, or deficiency of equipment, machinery and construction tools, or by defects in the machines itself, had to be demolished, rebuilt or repaired by account of the responsible of the work done, and also have the responsibility to remove the rest defective materials or elements off the workplace.

The equipment, machinery and tools provided by the subcontractors for the execution of the work should be adequate and sufficient to meet the requirements of the technical specifications.

General contractor reserved the right to reject and require replacement or repair, at the subcontractor expense of those equipment, machinery and tools that , in his view, are inadequate or insufficient to complete the task, either by equipment's nature or that could constitute danger to the rest of staff, or prevent the proper development of the works .

3.4. Subcontracting

As a way to reduce workload, the general contractor chose to outsource certain budget lines not related to construct directly. Tasks such as earthwork, electrical wiring layout in project infrastructure and landscaping were put into competition between other companies by choosing the best deal and design that is adapted to the project and also being economically feasible.

The general contractor also had the ability to outsource certain minor works with organizations in the surrounding communities. This was in order to obtain working staff of nearby places the worksite to maximize the working time. But the time saved idea looked eclipsed due to the lack of experience possessed by workers.

Although various workshops were handed to several others, at all times the general contractor was always the highest authority, taking responsibility for all work performed . In addition, all subcontractors must be affiliated to social security, or else they could not be authorized to carry out the work .

3.5. Social-environmental responsibilities

The socio-environmental aspect was a very important component of the contract. Before any work started in the area, a social gathering took place in which it was explained to the residents of the community about the works to be taken and set were required subjects linked to interventions.

In addition, prior to the commencement of the work, a document was signed between the general contractor and the community council. This document recorded the current state of where they would perform the works, adjacent buildings and adjacent structures, roads and other structures place, accompanied by the respective photographic record, if deemed appropriate.

With the idea of hiring workers near the project areas, all staff that was about to participate in the execution of the work, had to be employed directly by the Contractor, in accordance with the legal procedures, in order to avoid disagreements and problems with hired workers and maintain an environment of order.

4. Chapter 4: Project Analysis

4.1. Data collection

Data collection belongs, on one hand, to technical information about this research; and on the other, the entire contract documentation and study works. There is extensive literature on the subject of rework and various documents were consulted about research on this subject, although it should be noted that there are fewer studies done on real scenario projects. There were no studies found with similar specifications to the project analyzed in this master thesis. However, it is possible to obtain the guidelines and main ideas of the studies to other projects.

About the information on the contract, it was obtained basically from being part of the project at the time of its construction. Most documents were received by the contracting entity and some others were built along the way, as are the records of payment, which are essential to be certain about the exact quantities executed, after the project had the amount so significant changes that won.

The information not recorded nor available had to be requested from various parties involved in the contract, such as construction partners and former co-workers. Other situations had to be brought from memory to be included on this document. Accessing the work log information was not possible, because once the contract was filed, the journal is under promoter power only.

All incidences occurred during the life of the project are divided in three parts. The first part includes construction defects made by previous contractor while managing phase 1 houses. As the author of this master thesis was not present at the time being, nor didn't participated on this stage, all incidences mentioned below had to be inferred from construction and design defects founded during repair stage in the same houses.

Second part encompass all incidences related to repair errors made under new contractor management on phase 1 group houses.

On another hand, third part includes a list of construction incidences while developing and building phase 2 houses, also under new contractor management. All nonconformities that happened, no matter if could be quantified or not, are listed in section 4.3 according to the incidence classification described in section 4.2.

4.2. Terminology of rework incidence causes

The project selected for this case study experienced significant changes in several budget items, including a number of additional jobs; some product of redesign stage and others due to solicitations either from customers or promoters. Whatever these causes could be, it added new costs due to changes, errors, omissions or other situations that led to the emergence of rework .

Commonly rework during project development is not formally measured because the regular perception is that it is a normal situation generated by different aspects and often involves just minor repairs. In addition, there is a general idea that the most important thing is to repair as quickly and discreetly as possible, and to recognize a context of poor quality or running can damage the corporate image of the company or be subject to reprimands and fines.

Additional costs can be attributed to an external event, either a mistake or transmission of incorrect or non confirmed information or the emergence of additional works , which are expected to advance in these types of projects.

Only when those relate to poor or lack of quality finishes, are directly charged to the contractor, therefore, should be borne at its own expenses. On another hand, customer modifications, environmental conditions and other external situations contributed, in this case, to higher or modification costs, but it's not a responsibility of the promoter to emend this errors.

The presence of rework and its consequences are painful terms for the contractor, as they have a negative connotation, and from the first incident, it can cause distrust in the promoter and in the auditing, who becomes more demanding and prevented.

As mentioned in previous section, the work was performed in a different order from the numbering, so the work scheduling was done based on the closeness between the subprojects and neighborhoods, but other agents were instrumental in the decisions that were taken, especially during the first interventions. Another fact to add is that some tasks, not necessarily related and from different nature, were done without a linear sequence to maximize production time.

In order to create a functional model, is imperative to classify and group the list of incidence mentioned in the previous title, according to the nature of the problem. After that step, the causal root is going to be extracted so similar incidences are grouped into one single denomination in order to answer the questions "why" and "how to" rework occurred inside the project. An observation of the events took place, and the subsequent analysis of the documentation to accomplish this task.

With this information, a classification of causes of rework was performed based on three variables: Project, Organization and Human, which will be presented next ahead, according to the ideas presented by (Love P. , 2002), which has conducted similar investigations and revealed that rework could be classified in this way. This classification has allowed the common factors that contribute to causing rework in the sub-projects can be identified more clearly.

4.2.1. Project

Project scope modification: it is any modification made by customer request after the award of the work. Includes all changes occurred, whether significant or small. The main cause of changes to the work scope was poor preparation of the initial budget due to the rush in delivering documentation to the promoter. Because of this, omission of some necessary works, activities or vital information on specific procedures happened.

Over reliance of promoter in previous contractor: this is related to the previous relationship between promoter and his overconfidence with previous general contractor. This situation

Budget poorly developed: the budget seems to have been prepared without detailed knowledge of the intervention sites, as presented some inconsistencies that could have been avoided with a technical visit. Another important factor is that budgeting was made several months before the execution, due to the processes of recruitment, and in this course of time, the workplace was neglected and had no maintenance whatsoever. These changes in the initial budget were expressed specifically in terms of extra work, material substitution due to exhaustion of stock, additional requirements of the final owners of the property and carrying out very detailed work that could not be quantified in a simple way.

Incorrect designs: this situation happens when during project conceptualization stage, if a decision taken by designer on any matter doesn't comply the requirements for which it was designed, for example, a material that can't resist the environment in which is placed.

Lack of designs: for the execution of the project, the general contractor didn't receive complete specific designs, except in very special cases or major structural calculations, as in the case of retaining walls, support columns, etc..

Therefore, the exact location of scales was unknown and design schemes had to be done during contract development. This process took place over a period of a month, so that at first the work performed were not done quite right or the specified accuracy.

Deterioration of site: This occurs when the workplace is unattended and without constant maintenance. The natural agents deteriorate the site to a point where it should start from the beginning all process of construction or repair, losing all work actually done.

Pressure to start/complete tasks: urgency by the customer or auditing entity, due to the urgency of starting or delivering a specific work. Works were started without having all the information and resources at hand and work staff wasn't sufficiently prepared for embracing the job, forcing the site crew deciding on site and even have temporary suspensions.

Uncertainty: it has to do with the inaccurate knowledge of situations referred to places of intervention, type of work, exact locations, reasons or motivations of the community, not timely notified changes by the promoter, among others.

Theft and vandalism: corresponds to the thefts made by the common or organized crime materials and construction tools.

Weather conditions: on occasions, rain and bad weather conditions prevented advance work, or at night, ruined concrete that had been left in place, because there were no implements to leave covered. In program schedule, the project had forecasted at least one day of rain on every week to avoid delay on delivery time.

Third parties damages: basically is damage or deterioration over works recently completed, resulting in at night or any damage caused to the infrastructure project by outsiders to work.

Confidence in the project: situation that involves reasonable doubts, and lack of thrust among all participants related to the project who have skeptical thoughts and are not convinced about its final outcome.

Modifications solicited by customer: this item cover all extra solicitations from final customer that aren't covered in the original design.

Interruption of project: this subjects talks about total paralization of works due to disagreements between promoter and contractor. When these parts don't get to a common understanding, all works all are immediately ceased until reaching an agreement

Interruption of public services: water and electricity were seen irregularly interrupted, which paralyzed the work until the service is reinstated.

Interface between contractors: misunderstanding and lack of communication and coordination between contractors when organizing their groups, in case they would work simultaneously in the same place, causing disruption and delays between each others.

Visits of promoter/customer: promoter and customers visits could cause effects in detrimental to the project. They could require changes to product or work scope, cause delays in documentation approval, supply of essential information, require a high level of budget and progress reporting or can tighten milestone schedules (G. Rodriguez & M. Williams, 1998).

The influence of promoter and/or customers could have widely negative consequences for project's development. These actions could have repercussions in the project reducing productivity rate, distrust between the working members and not fulfilling programmed schedules.

As said by (G. Rodriguez & M. Williams, 1998), the relationship between the promoter and the contractor during the project can be characterized by two different communication processes. On one hand, a continuous progress reporting from contractor regarding the major milestones with the purpose to keep the customer confident about project development. On another hand, promoter requires continuous review of the system definition and its required functionality, aiming to ensure a clear understanding of the definition of the product being developed.

The authors (G. Rodriguez & M. Williams, 1998) clarify that, as the contractor fails to meet milestones, the promoter feels the right to compensation while reducing his trust in the contractor's competence. Alternatively, the contractor's means of recovering the short-term milestones might be at the expense of worse over-runs later.

Also, these unexpected visits from customers disturbed day's programmed schedule, and with their constant presence around the site disturbed all workers, impeding workers to achieve their peak performance, because all focus had to be on cleaning the site so the owner could pass through and oversee the progress achieved.

Customer presence: on repair stages, the owner was already living on the house, and having them around the worksite at all times posed a problem to work developments. Customer had no thrust in repair development and for this they applied pressure into workers to complete tasks as fast as possible but at the same time soliciting new tasks to be done, which were outside of original scope. This situation prevented work staff of doing their job properly.

Extra work: these changes are applied to final product due to unexpected events and need other modifications necessarily to accomplish the task successfully. Not to be confused with customer's modifications or new changes solicited.

Concealment of information: This situation is a practice that contribute on the amount of rework produced in a project It happens when project managers hold information back on what their real schedule is and how much rework they encounter and push downstream. (Pei-Yin Feng, 2009). Project managers intention is to hold information in hopes someone else among the project teams will eventually have to come forward and state they are behind schedule. Then the rest of the project team can add time to their schedules allowing them to cover up errors.

This situation occurs due to the multiple handoffs between the project players. Each participant says they are on schedule yet may be behind schedule, in hope to find time to correct errors, and delaying the release of more complete information. Managers often conceal information for several reasons, which, according (Ford D. , 2003a); (Sterman J. , 2002); (DeMarco, 1982); (Kiewel, 1998), are:

1. Reduces the need for iteration (temporarily), which increases leadership's perception of schedule completion.

2. Reduces the amount of known work that needs to be reworked and further coordinated, improving apparent project quality.

3. Delays coordination so that rework spreads the work over a longer period of time, reducing peak resource needs.

4. Leads to rework that increases the chance that schedule delays by other phases will allow managers and engineers to solve their own issues.

In like manner, some effects that concealment could have on a project can be: significantly lengthens project durations, increases cost, and reduces quality; leads to smaller cycle time reductions experienced by concurrent development. Also, concealment has a greater impact when high concurrence occurs because more work has been done with errors that are concealed until finally detected at the end of the project.

4.2.2. <u>Organization</u>

Supervision problems: refers to poor supervision by staff or contractor auditing and allowing the occurrence of incidents, such as misinterpretations, or from lack of experience.

Design changes: it is any change in one of the designs received or subsequently approved by social or technical reasons.

Delay time: this situation happened when certain work or milestone deadline would be completed late and not on the date specified on the chronogram.

Unexpected events:. This section includes any situation that may arise unexpectedly and for whatever reason could not have been anticipated before. Some examples that can be mentioned are: a situation resulting from excavation activities and finding a service pipe not expected, whether because they were buried or not specified on blueprints, de-protection of walls and other items when doing repairs in the roof or temporary suspension for nonpayment or affiliation to social security may be included.

Unrealistic schedules to complete tasks: it's a situation when time frame is so constraint to complete a task or a job, that it's practically impossible for contactor to deliver the work on time, but promoter expect result by the date previously established

Management resolution time: at several times, waiting for promoter to approve a modification or any decision that matters, the time waiting was overmuch, causing time loss on site

Budget mismanagement: Refers directly to the missing economical resources at work, preventing from performing activities as they should be done.

Late delivery of materials: this situation occurs when supplies requested to contractor's office or supply offices don't arrive on time to the project, causing delay on performing tasks scheduled for that particular day.

Staff continuity: old workgroups who knew all details about project couldn't or didn't continue working on site, and new workers had to be hired to continue working.

Over reliance on 3-D CAD: over confidence on CAD blueprints without having done a field inspection and verify the accuracy of measure and if they match with the information back in office

Resourcing and planning problems: during project execution there were situations while performing any activity in which it seemed that there was not any planning of tasks, nor layout of teams in small areas or the supplies and tools needed to perform more specialized task. This lack of foreseeing in a global way a schedule of activities for a day kept workmen confused and without support from the management team. This category also includes problems with chain of supply of materials to perform works

Inadequate communication: Lack of communication in the workplace can occur on a large scale, such as between management and employees, as well as on a smaller scale between individual employees. Failure to communicate effectively often leads to conflict, which can harm an organization. Poor communication can create conflict in a number of ways, such as uncertainty, distribution of wrong information and poor teamwork. mistakes

Economic problems: projects economic liquidity fails to meet all payment responsibilities due to incorrect management of funds.

Acceleration: this factor is the increasing rate of velocity at which works are done. This was usually used when pressure to finish pendant work or to reach upcoming delivery date.

4.2.3. Personal

Stress: worrying situation that were presented primarily on workers, due to the general pressure in the work, the changes, the complexity of the interventions and the lack of time, and that caused poor performance, errors and / or confusion. In some cases was associated with extensive internal transport.

Workmanship errors: this category include all mistakes committed by workmen performing their jobs This can include situations such as task performed without caring or paying attention to what is being done, lack of prior knowledge or bad execution of tasks, or when workers were not performing at their best capacities

Omission of checks: refers to a lack of attention when a workman has finish to do a task, but didn't perform a final check looking for flaws in the job already done.

Distribution of wrong information: is false, inaccurate or outdated information that is spread unintentionally, and in most cases, without knowing if source is confident or secure

4.3. Project incidences

This section describes the incidences related either to construction or repair stages within the project. Next, each house is taken as a subproject to be examined and analyzed according to the classification described before on section 4.2. This classification of information helps to analyze and understand each incidence with their respective causes and responsible specified. It is important to emphasize the order of houses presented next ahead is not the same order as incidences and nonconformities were addressed and resolved.

The analysis of the first group of houses built is going to be divided in two sections. A first approach is focused on construction incidences after completing phase one houses under previous contractor. These incidences emerged due to errors during design conceiving and construction stages while developing this first group of houses This amount of incidences generated defects and discomforts with the customer and the houses needed to be repaired by any means.

A second approach relates the incidences linked to repair jobs while correcting previous construction defects in Phase one houses. This situation was a different scenario because the owners were already living in the houses while repair tasks were being performed and developed. The third and final approach shows the list of incidences related to Phase 2 construction stage under new contractor management. In this phase there were 8 houses, 2 warehouses and the entrance booth in construction development, generating all kind of incidences that eventually leaded into rework arise.

An important objective of this analysis is to link the incidences with its respective causes that occurred during construction stage within phase 1 and 2 development and conceive a general model that represents and encompass rework's behavior in this particular stage. On another hand, repair incidences are going to be modeled in a separate model and observe how rework is generated in this stage, although the incidences are not related at all with construction stage.

4.3.1. Part one: Defects detected after completing phase One

In the following section are going to be listed the incidences related to construction defects made by previous contractor on the 10 first delivered houses that compose phase one.

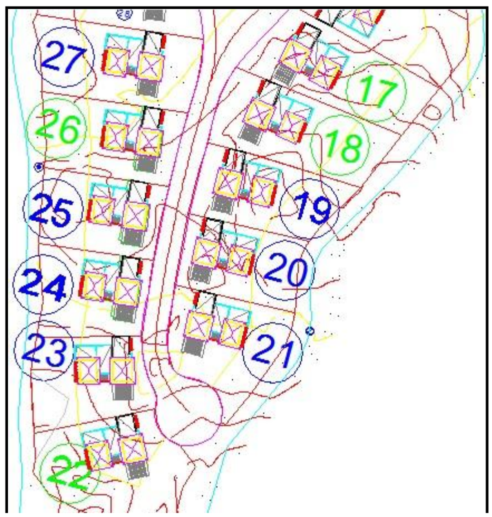

Fig. 4.1: List of houses with construction incidences

It is important to remember that incidences mentioned in this section are entirely based on inferring the causes from all problems that houses had after customers received it, , and this is why is possible to create a list of reasons that could may have occurred, causing the actual problems. Houses marked in green numbers are the ones which reported construction defects during previous contractor management. After listing all nonconformities and incidences, common and most relevant variables can be extracted and compared with the rest of the houses in construction under new contractor.

The main goal, in an holistic way, is to be able to compare the differences between incidences that happened both in phase one and two construction stage: same environment, but different time, and with several factors involved in rework's final outcome. Afterwards, observe if a link exist between construction stages on both phases for creating a System Dynamic model that covers the entire project.

4.3.1.1. House no. 17

This house had several problems right after the customer moved in. Among the common problems present were roof leaking, low quality materials on waterproofing protection in roof, wrong slopes in windows sills and living room floor allowing rain to enter inside the house. Also, wood elements were rotted and had to be replaced for iron to reduce house maintenance. Due to the long list of problems in this house and outcome inconformity of the customer, repairs were priority to be done immediately in this case. Table 4.1 shows house 17 construction incidences list that caused rework under previous contractor.

Table 4.1: House no. 17 construction incidences list.

House no. 17 Construction Incidences								
Incidence	**Causes**	**Description**	**Responsible**	**Nature**	**Time increase**	**Cost increase**		
						Promoter	**Customer**	**Contractor**
Wooden elements got rotted due to near sea environment	Incorrect design	Wood elements got damaged by sea environment	Previous designer	Project	-	3,409.85 €		
Pool walls had not water coating protection seal applied correctly	Lack of design	Pool walls didn't had water protection coat			-	68.63 €		
All works on the project got paralyzed	Interruption of project	Project works ceased due to misunderstanding between promoter and previous contractor	Promoter, previous contractor		2 years	-		
Granite slurry applied on external kitchen hallway	Modification solicited by customer	Customer solicited external hallway with granite slurry top	Customer		1 day		43.44 €	
Delay on payments to contractor	Budget mismanagement	Promter didn't pay contractor on time	Promoter	Organization	-			-
Floor tiles model was no longer available	Resourcing and planning problems	Supply store ran out of stocks on tile model	Supplier		4 days			-
Demolish and replace floor tiles with wrong slope		Balcony floors had inverted slope			-			236.18 €
Water leaking through walls damaged wall painting		Walls didn't have external watercoat protection			-			-
Windows sill had inverted slope		Windows sill allowed water enter the house due to inverted slope	Foreman		-			55.62 €
Pool water pump broke due to wrong installation	Workmanship errors	Water pump wasn't installed correctly	Technician	Human	-	713.80 €		
Closet flooded due to water leaking from bathroom window		Bathroom window was not sealed at all and water entered into closet	Workman		2 days			-
Roof leaks allowed water to enter and damaged furniture		Roof had several leaks	Foreman		-			-
Water leaking in kitchen's roof damaged light bulb and ceiling		Water leak through roof caused damage on kitchen			-			-
Door accesories not installed correctly	Omission of checks	Door jambs and locks installed didn't function	Door installer		-			-
Second room balcony drain had no finishing at all		Balcony drain was installed with no finish work	Workman		-			-
Main room balcony exterior wasn't painted		Balcony walls weren't painted			-			-
Low performance on workers to complete duties	Stress	Workmen weren't performing as expected	Contractor		-			-

4.3.1.2. House no. 18

In this house, the main construction mistakes made were roof water leaking, a design error choosing wood elements as decoration near sea environment and windows sills and balcony floor had inverted slope, leading the water into the house. Table 4.2 presents all incidences that occurred related to construction stages under previous contractor.

Table 4.2: House no. 18 construction incidences list.

House no. 18 Construction Incidences								
Incidence	**Causes**	**Description**	**Responsible**	**Nature**	**Time increase**	**Cost increase**		
						Promoter	**Customer**	**Contractor**
Wooden elements got rotted due to near sea environment	Incorrect design	Wood elements got damaged by sea environment	Previous designer	Project	-	3,409.85 €		
Roof had several water leaks	Lack of design	There was no water coat protection on roof			-	68.63 €		
All works on the project got paralyzed	Interruption of project	Project works ceased due to misunderstanding between promoter and previous contractor	Promoter, previous contractor		2 years	-		
Delay on payments to contractor	Budget mismanagement	Promoter didn't pay contractor on time	Promoter	Organization	-			-
Windows sill had inverted slope	Supervision problems	Windows sill allowed water enter the house due to inverted slope	Foreman		-			55.62 €
Water leaking in kitchen's roof damaged light bulb and ceiling		Water leak through roof caused damage on kitchen			-			-
Water leaking through walls damaged wall painting		Walls didn't have external watercoat protection	Previous contractor		-			-
Backyard external door sill had no slope	Workmanship errors	Door sill had no slope allowing water to enter into house	Workman	Human	-			-
Windows sill had inverted slope		Worker didn't apply slope on window sill			-			12.78 €
Multiple roof leaks allowed water to enter and damaged house interior		Roof had several leaks			-			-
Balcony drain had no finishing at all	Omission of check	Balcony drain was installed with no finish work			-			-
Main room balcony exterior had no paint finishes on walls		Balcony walls weren't painted			-			-
Low performance on workers to complete duties	Stress	Workmen weren't performing as expected	Contractor		-			-

4.3.1.3. House no. 22

This house had a particular importance in the project because it served as a model example to show new customers how the final product would look like. Several construction errors were carried by previous contractor, specifically in bathroom area. Inside, the shower floor had no slope at all, water leaking through the roof ruined the ceiling and when replacing floor tiles after fixing the slope, there were no more stocks of the same model in suppliers warehouse. Also wood elements weren't the best choice for an environment near to the sea.

Table 4. 3 shows all incidences that lead into rework in construction scenario.

Table 4. 3: House no. 22 construction incidences list.

House no. 22 Construction Incidences								
Incidence	**Causes**	**Description**	**Responsible**	**Nature**	**Time increase**	**Cost increase**		
						Promoter	**Customer**	**Contractor**
Wooden elements got rotted due to near sea environment	Incorrect design	Wood elements got damaged by sea environment	Previous designer	Project	-	3,409.85 €		
Roof had no watercoat protection applied	Lack of design	Roof didn't have water protection coat			-	68.63 €		
All works on the project got paralyzed	Interruption of project	Project works ceased due to misunderstanding between promoter and previous contractor	Promoter, previous contractor		2 years	-		
Customer solicited to repaint house internal and external wall's	Modification solicited by customer	Customer asked to repaint external walls	Customer		-			-
Delay on payments to contractor	Budget mismanagement	Promoter didn't pay contractor on time	Promoter	Organization	-			-
Floor tiles model was no longer available	Resourcing and planning problems	Supply store ran out of stocks on tile model	Supplier		4 days			-
External door crystals not sealed correctly	Supervision problems	External doors weren't sealed correctly	Previous contractor		-			-
Demolish and replace floor tiles with wrong slope		Balcony floors had inverted slope			-			236.18 €
Water leaking through walls damaged wall painting		Walls didn't have external watercoat protection			-			-
Windows sill had inverted slope		Windows sill allowed water enter the house due to inverted slope	Foreman		-			55.62 €
Windows sill had inverted slope	Workmanship errors	Worker didn't apply slope on window sill	Workman	Human	-			12.78 €
Multiple roof leaks allowed water to enter and damaged furniture and decorations		Roof had several leaks			-			-
Water leaking in kitchen's roof damaged light bulb and ceiling		Water leak through roof caused damage on kitchen			-			-
Second room balcony drain had no finishing at all	Omission of checks	Balcony drain was installed with no finish work			-			-
Main room balcony exterior had no paint finishes on walls		Balcony walls weren't painted			-			-
Demotivation on workers to complete tasks	Stress	Workmen weren't performing as expected	Contractor		-			-

4.3.1.4. House no. 26

Same as house no. 18, , the main construction mistakes made were roof water leaking, a design error choosing wood elements as decoration near sea environment and windows sills and balcony floor had inverted slope, allowing external water entering into the house. Table 4.4 presents all incidences that occurred related to construction stages under previous contractor.

Table 4.4: House no. 26 construction incidences list.

House no. 26 Construction Incidences								
Incidence	Causes	Description	Responsible	Nature	Time increase	Cost increase		
						Promoter	Customer	Contractor
Wooden elements got rotted due to near sea environment	Incorrect design	Wood elements got damaged by sea environment	Previous designer	Project	-	3,409.848 €		
Roof had several water leaks	Lack of design	There was no water coat protection on roof			-	68.627 €		
All works on the project were paralyzed	Interruption of project	Project works ceased due to misunderstanding between promoter and previous contractor	Promoter, previous contractor		2 years	-		
Delay on payments to contractor	Budget mismanagement	Promoter didn't pay contractor on time	Promoter	Organization	-			-
Windows sill had inverted slope	Supervision problems	Windows sill allowed water enter the house due to inverted slope	Foreman		-			55.621 €
Water leaking in kitchen's roof damaged light bulb and ceiling		Water leak through roof caused damage on kitchen			-			-
Water leaking through walls damaged wall painting		Walls didn't have external watercoat protection	Previous contractor		-			-
Backyard external door sill had no slope	Workmanship errors	Door sill had no slope allowing water to enter into house	Workman	Human	-			-
Multiple roof leaks allowed water to enter and damaged house interior		Roof had several leaks			-			-
Balcony drain had no finishing at all	Omission of check	Balcony drain was installed with no finish work			-			-
Main room balcony exterior had no paint finishes on walls		Balcony walls weren't painted			-			-
Low performance on workers to complete duties	Stress	Workmen weren't performing as expected	Contractor		-			-

4.3.2. Part two: incidences during repairs on phase One

The following section describes the objects and scope of the work contained in the contract repairing of phase 1 houses in the project "The Residence Club". Repaired houses are shown in Fig. 4.2: List of houses with repair works. marked with green numbers.

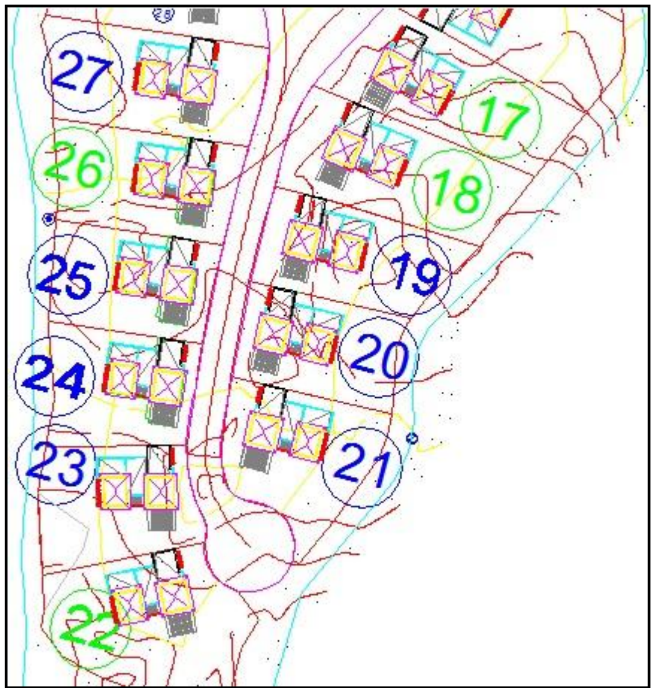

Fig. 4.2: List of houses with repair works.

The following segment presents the information of incidences that caused rework while performing repair duties to emend construction mistakes made by previous contractor. It has to be mentioned that the final owners were actually living in the houses while repair works were in develop.

The customers, if had any complaint, were sole responsible for filing and presenting the non conformities list of their houses to Promoter's project management office, so repairs could be inspected and evaluated in each house.

Although phase 1 repair works was a different contract from construction works on phase 2, there were very important repairs and modifications that ultimately leaded into major design changes on phase 2 houses. As both projects were next one to each other, it facilitated the transfer of control personnel, machinery, debris collection, supplies among others.

It is important to clarify that the execution order was not supposed to be done in the order listed, nor necessary to complete the work of the original contract, before addressing phase 2 contract. Both projects were developed simultaneously.

4.3.2.1. House no. 17

The customer of this house was truly upset because after 6 months he moved into the house, there were already severe water leaking problems through the roof, external paint was peeling off and pool was presenting filtration problems according to customer's point of view. All these incidences made the customer's getting demanding to promoter for delivering the house the way it was promised. Table 4.5 present the list of incidences that occurred while performing repair tasks on house no. 17.

Table 4.5: House no. 17 repair stage incidences list.

House no. 17 repair incidences								
Incidence	Causes	Description	Responsible	Nature	Time increase	Cost increase		
						Promoter	Customer	Contractor
Customer was already living in the house while repair tasks were performed	Customer's presence	Customer's presence in the house pose a difficulty to carry out works properly	Customer	Project	3 days		-	-
Workers were interrupted by customer solicitations		Constant interruptions by customer impeded workers from completing their tasks on time			-		-	
Customer was presuring for repairs to be completed as soon as possible	Pressure to start/complete tasks	Customer was presuring to complete repair tasks while personally supervising repair duties			-		-	
Extra repairs solicited not included in original scope	Extra works	Customer was demanding for new changes and different works not included in original scope			-		1,107.51 €	
Rain spoiled recently applied pullcoat protection	Weather problems	Water proof protection on pool was washed out by rain	-		1 day			46.35 €
Delay on approving authorization to start repairs	Promoter's resolution time	Promoter took long time to approve repair tasks	Promoter	Organization	2 days			-
Stair's paint was peeled off and scratched	Work staff clash	Stair's paint was scratched and peeled due to work staff passing through	Work staff		-			
Repair supplies arrived late	Resourcing and planning problems	Supply order was solicited too late	Contractor		1 day			-
Repair task couldn't be delivered on scheduled time	Delay time	Repaired house couldn't complete tasks on time			2 days			-
Stove crystal surface broken by paintor	Workmanship errors	Paintor dropped brush over crystal top	Workman	Human	-	74.75 €		
Broken light bulbs while repairing roof lamp in kitchen		Techinician moved his tools and smashed the light bulb	Technician		-			4.32 €

4.3.2.2. House no. 18

The customer of this house was constantly demanding to promoter to resolve all construction incidences left by previous contractor, but on days scheduled for repair tasks, there was no one on the house to receive the staff, causing delays on final delivery time. Although house problem's weren't very serious, customer constant presence in house supervising and soliciting changes and repairs out of original scope presented an impediment for workers to perform their work as expected. On Table 4.6 are listed the incidences related to repair stage on house no. 18

Table 4.6: House no. 18 repair incidences list.

House no. 18 repair incidences								
Incidence	**Causes**	**Description**	**Responsible**	**Nature**	**Time increase**	**Cost increase**		
						Promoter	**Customer**	**Contractor**
Customer was already living in the house while repair tasks were performed	Customer's presence	Customer's presence in the house pose a difficulty to carry out works properly	Customer	Project	3 days		-	-
Workers were interrupted by customer solicitations		Constant interruptions by customer impeded workers from completing their tasks on time			-		-	
Customer was presuring for repairs to be completed as soon as possible	Pressure to start/complete tasks	Customer was presuring to complete repair tasks while personally supervising repair duties			-		-	
Extra repairs solicited not included in original scope	Extra works	Customer was demanding for new changes and different works not included in original scope			-		648.54 €	
Delay on approving authorization to start repairs	Promoter's resolution time	Promoter took long time to approve repair tasks	Promoter	Organization	2 days			-
Promoter didn't notify Customer about the date of doing repairs	Inadequate communication	Workers arrived at house but no one was at home			1 day			
Livingroom wall paint was peeled off and scratched	Work staff clash	The wall paint on livingroom got scratched and peeled due to work staff passing by	Contractor		-			32.65 €
All workgroups were messing each others job	Resourcing and planning problems	Poorly layout planning since all team work couldn't be at the same time in the area			2 days			-
Floor tile model out of stock	Supply of materials	Supplier ran out of stock with tile model	Supplier		2 days			-
Workman damaged furniture around work area	Workmanship errors	Paintor messed the furniture with splash of paint	Workman	Human	-			-
Workman dropped tool and broke a tile		Floor tile was broken by workman and had to be replaced			-			-
Workers left unfinished jobs	Omission of checks	Several tasks were not totally finished			-			-

4.3.2.3. House no. 22

On house no. 22, repair duties were carried out with certain delicacy, because this house was the model show and example to promote the entire project. This house allowed new customers to have a full view of the final product on sale. For this matter, in this house, wood decorative elements were not replaced, although in the final product delivered to customers had been replaced for iron elements. All modifications and repair jobs were charged to the promoter, because the house hadn't been purchased by no one at the time.

The most important repair was made to the main room bathroom. Inside, the shower floor had no slope at all, supplies used in it were out of stock for the rest of houses and had water leaking in the ceiling, ruining the ceiling. Table 4.7 mentions the incidences that lead into rework during repair stage under new contractor.

Table 4.7: House no. 22 repair incidences list.

House no. 22 repair incidences							
Incidence	**Causes**	**Description**	**Responsible**	**Nature**	**Time increase**	**Cost increase**	
						Promoter	**Contractor**
Promoter was pressuring for repair tasks were done as quick as possible	Pressure to start/complete tasks	Promoter was pressuring to finish repairs in model villa	Promoter	Project	-		
New tasks were necessary to complete the repair work	Extra works	Several repairs caused by design errors from previous contractor had to be fixed	Previous contractor				
Rain conditions prevented placing watercoat protection on roof	Weather problems	Rainy days didn't allow to place watercoat protection on roof on day planned	-		2 days		-
Delay on releasing funds to start repair tasks	Promoter's resolution time	Promoter took long time to deliver funds to repair the villa	Promoter	Organization	2 days		-
House was closed on date of repairs	Inadequate communication	Promoter didn't notify house manager about date of repairs			1 day		
Spare parts for repair tasks ran out of stock	Resourcing and planning problems	Supply order was solicited too late	Supplier		1 day		-
House furniture was affected by workman	Workmanship errors	Workman didn't protect surrounding area and damage the furniture	Workman	Human	-	74.75 €	
Broken light lamp with stair		Workman moved a stair and smashed the light lamp			-		12.45 €
Repair tasks not fully completed on time		Lack of payment demotivated workers, lowering their performance	Contractor		-		-
Workers couldn't concentrate to finish repair tasks	Stress	Workmen got stressed due to extreme pressure to finish duties	Promoter		-	-	

4.3.2.4. House no. 26

Similar to house no. 18, the customer that owned the house had a lot of complains when moved in. Besides water leaking, there were wrong slopes on windows and floors and wood elements were rotted completely. The major task to accomplish was replacing the previous waterproofing material on the roof and apply a new layer and a sealing product to prevent water leak. Table 4.8 presents all the incidences occurred during repair tasks developments which leaded into rework in house no. 26.

Table 4.8: House no. 26 repair incidences list

House no. 26 repair incidences								
Incidence	Causes	Description	Responsible	Nature	Time increase	Cost increase		
						Promoter	Customer	Contractor
Customer was already living in the house while repair tasks were performed	Customer's presence	Customer's presence in the house pose a difficulty to carry out works properly	Customer	Project	3 days		-	-
Workers were interrupted by customer solicitations		Constant interruptions by customer impeded workers from completing their tasks on time			-		-	
Customer was presuring for repairs to be completed as soon as possible	Pressure to start/complete tasks	Customer was presuring to complete repair tasks while personally supervising repair duties			-		-	
Extra repairs solicited not included in original scope	Extra works	Customer was demanding for new changes and different works not included in original scope			-		954.78 €	
Rain conditions prevented placing watercoat protection on roof	Weather problems	Rainy days didn't allow to place watercoat protection on roof on day planned			2 days			-
Delay on approving authorization to start repairs	Promoter's resolution time	Promoter took long time to approve repair tasks	Promoter	Organization	2 days			-
Livingroom wall and stair paint was peeled off and scratched	Work staff clash	Paint on livingroom wall and stairs was scratched and peeled due to work staff passing by	Contractor		-			32.65 €
Repair task couldn't be delivered on scheduled time	Delay time	Repaired house couldn't complete tasks on time			1 day			-
All workgroups were messing each others job	Resourcing and planning problems	The entire work staff couldn't be at the same time in the area			2 days			-
Floor tile model out of stock		Supplier ran out of stock with tile model	Supplier		2 days			-
Workman damaged interior decoration in house	Workmanship errors	Paintor messed the furniture and decoration with paint	Workman	Human	-			-
Workman dropped tool and broke a tile		Floor tile was broken by workman and had to be replaced			-			-
Workmen didn't clean area after finishing their work		Work area was left dirty			-			-
Bad finishes after completing repair tasks	Omission of checks	Several tasks were not done correctly			-			-

4.3.2.5. Dumpster enclosure

Due to a crash accident, a garbage truck hit and destroyed half of the dumpster enclosure. Repair works were done immediately to avoid complains of neighbors. General contractor asked the promoter about how to handle costs of repairing the dumpster, but the promoter delayed the answer for some time, so repair duties had to be performed using material, supplies and workers from phase 2 construction. In this way it was possible to patch up the enclosure wall in no time. Table 4.9 shows the list incidences caused by the accident.

Table 4.9: Dumpster repair incidences list.

Dumpster enclosure repair incidences							
Incidence	**Causes**	**Description**	**Responsible**	**Nature**	**Time increase**	**Cost increase**	
						Promoter	**Contractor**
Garbage truck smashed dumpster enclosure	Third party damage	Garbage pickup truck crashed into dumpster walls	Garbage truck driver	Project	-	-	
Presure from promoter to complete repairs duties	Pressure to complete tasks	Presure from promoter to repair dumpster as soon as possible	Promoter		-	-	
Delays on pay the workers for repair works	Economic problems	Payment to workmen were delayed by promoter	Promoter	Organization	1 day	-	
Poor finishes in dumpster walls	Resourcing and planning problems	There were not enough supplies on warehouse to repair dumpster	Foreman		-		-
Poor performance from workers	Stress	Workmen were stressed due to pressure to finish	Contractor	Human	-		-

4.3.3. Part three: construction incidences on phase 2 houses

In this stage of the project we enter into the construction phase of a new group of houses already started by a previous contractor, but were left unfinished due to economical disagreements with promoter. All incidences listed next are related only to construction stage, which ultimately leaded into the major amount of rework within the whole project.

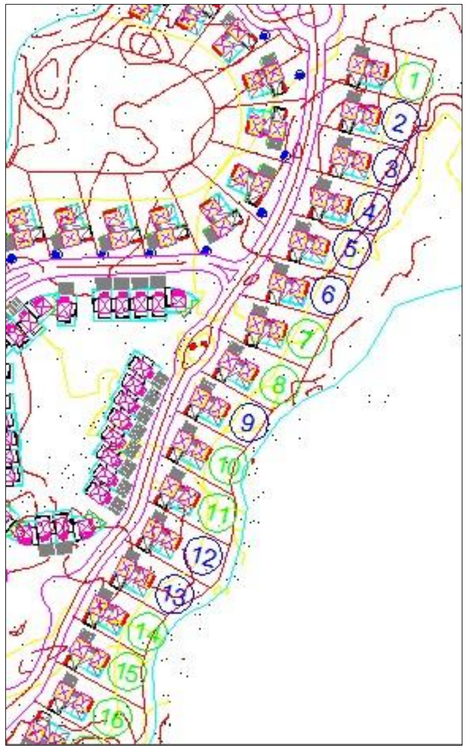

Fig. 4.3: List of houses with construction incidences

When the new contractor came to visit the job site for the first time, the 16 houses of this phase were finished structurally speaking. This means the house's frame were already built, but with no finish whatsoever. The scope, as planted later on contract, was to finish the houses and deliver them to the final customers.

As mentioned before, the house design had some flaws dragged from previous phase, and the main scope was to turn the house into profitable and attractive product for the promoter. This is why there is an item in phase 2 budgets that encloses all design changes and adjustments made during re-design process stage. The incidence list shown next are related to the houses that were pending to be delivered first to final customers. The promoter communicated to the general contractor the houses had to be delivered in a span of two months.

The procedure to follow was simple; list every detail needed to complete the product and avoid sequential tasks. To maximize time, similar jobs in each house had to be addressed almost simultaneously, but eventually this ended leading into several incidences with work clash and creating a poor use of resources.

4.3.3.1. House no. 1

This is the first house at the entrance of the project and it could be noticed that it was slightly different to the other ones. First of all, house no.1 plot terrain was not a regular square, so it had a big back yard garden, but the front garden was smaller than the rest of the houses. This inspired the final owner to do certain modifications at his own taste, which delayed the final delivery date. The incidence list is shown on Table 4.10.

Table 4.10: House no. 1 construction incidences list.

House no. 1 construction incidences								
Incidence	Causes	Description	Responsible	Nature	Time increase	Cost increase		
						Promoter	Customer	Contractor
Customer solicited new material for external decoration on backyard	Modification solicited by customer	Substitution of granite slurry for concrete steps w/ ceramic tile top in backyard area	Customer	Project	2 days		0.009%	
Extra light outlet in main room		Solicitude of extra light outlet on main room			-		0.005%	
Removal of windows hollow on main room closet		Customer solicited removal of closet window			-		0.001%	
Wooden deck removed in pool area		Wood deck removed from pool			-		-	
Low resistance concrete in sustitution of wooden deck		Sustitution of concrete deck instead of wood			4 days		0.008%	
Water line communication from filter to kitchen area		Water line comunication line from water pump to fridge			-		0.001%	
Extra TV outlet in livingroom		Extra antenna TV outlet installation on living room			-		0.001%	
Pantry installation in previous hollow space for fridge		Customer solicited to modify pantry space to fit a fridge			-		0.020%	
Wooden deck floor above main entrance area for second living room		Wood deck over entrance to make a second living room			10 days		0.046%	
220-240 V extra outlet installation		Extra electrical outlet solicited by customer			1 day		0.003%	
Extra A/C unit, with ducteries and electric installation		Extra A/C unit solicited by customer			12 days		0.077%	
Cabinet confection in room no. 2 closet		Modification of closet to make a cabinet for TV			15 days		0.020%	
Extra antenna TV outlet installation on room no. 2		Extra TV outlet in bedroom			-		0.001%	
110-120 V electric outlet on closet cabinet in room no. 2		Extra electrical outlet solicited by customer			-		0.001%	
Installation of bubble blower in pool sitting bench		Air blower for bubbles on pool solicited by customer			-		0.025%	
Confection of flanges around palms in garden area with ceramic finish		Decoration solicited by customer under palm trees			-		0.002%	
Led electric outlet in palm flange		Light decoration under palm trees in backyard			-		0.003%	
Confection of gas inlet for stove		Customer solicited an inlet of gas for stove, not used on project			7 days		0.006%	
Green wall to surround the house completely		Instead of fences, customer solicited a green wall to surround house			15 days		0.016%	
Unexpected visit from customer	Visit from customer	Surprise visits from customer soliciting new modifications			-	-		
Uncertainty among work staff about project final scope	Uncertainty	Confussion among work groups about promoter's indecision	Promoter		-			-
Substitution of rotten wood beams and plates in main roon roof	Deterioration of site	Roof elements made of wood were rotted due to unfinished job			14 days	0.206%		
All works within project were paralyzed	Interruption of project	Disagreements between Promoter and contractor due to Promoter's unabilty to make payments			90 days	-		
Rainwater ruined wooden roof and freshly watercoat protection	Weather problems	After watercoat was recently applied, rain remove it	Contractor		10 days			0.031%
Several groups of workers left the project	Confidence in the project	Workers had no faith on project succes and were quitting			15 days			-

Removal of two doors in room no. 2 closet due to cabinet installment		After modifying closet, doors had to be removed	Customer		4 days		0.011%	
Measure changes on pool excavation to fit terrain plot	Design changes	Pool measurements didn't fit on terrain plot and had to be modified			3 days			0.020%
Adapting house to new desing aproved by Promoter		Design erros corrected from phase 1 and adapted to phase 2				0.193%		
The corners of window and door openings weren't square	Supervision problems	Supervision didn't check if door and window hollows corner's were squared at 90 degrees	Contractor		-			-
Workers went on strike due to lack of payments after restarting the project	Budget mismanagement	Lack of payments made workers go into strike		Organization	12 days			-
Landscapping materials quantities were not calculated correctly		Garden material quantities werent't calculated correctly			2 days			-
Project works ceased due to financial inconvenients	Economic problems	No economic funds to pay workers	Promoter		90 days	-		
Delay of promoter on approving changes solicited by customer	Promoter's resolution time	Promoter was taking too long to approve customer's modifications			6 days	-		
Wood supplies arrived late for completing roof tasks	Late delivery of materials	Materials arrived several day late	Supplier		14 days			-
Performance of new workers hired was not productive as expected	Staff continuity	New group of workers had to be hired and trained	Previous work staff		14 days			-
Correcting windows sills slope that were inverted into the house	Workmanship errors	Workers weren't applying slope on windows sill as ordered	Workman		-			-
Old and new workers did not completed scheduled tasks on time	Stress	Workers weren't completing job task at time due to pressure	Work staff	Human	30 days			-
General concern wehter workers would receive payment		Workers were worried due to insecurity on payments	Contractor		-			-

4.3.3.2. House no. 7

In house no. 7, beside adapting it to the new design, all works done were only to complete the esthetic view of the final product. As seen on Table 4.11, the most relevant causes of rework were related to installing the A/C unit, finish building pool's walls and installing the iron elements that replaced the wood elements in the old design.

Table 4.11: House no. 7 construction incidences list.

House no. 7 construction incidences								
Incidence	**Causes**	**Description**	**Responsible**	**Nature**	**Time increase**	**Cost increase**		
						Promoter	**Customer**	**Contractor**
Promoter insecurity about final customer decision on buying the house	Uncertainty	Customer was hesitating about buying the house	Customer	Project	8 days		-	
Uncertainty among work staff about project final scope		Confussion among work groups about promoter's indecision			-			-
First floor area invaded by weed due to lack of maintenance	Deterioration of site	Work site was abandoned with no maintenance	Promoter		1 day	0.021%		
Change of priority in house final delivering	Project scope modification	Delivery priority was postponed further, without noticing workcrew			4 days	-		
All works within project were paralyzed	Interruption of project	Disagreements between promoter and contractor due to lack of payments			90 days	-		
Rainwater caused landslided in pool excavation	Weather problems	Pool excavation had no protection and rainwater caused landslide	-		3 days			0.024%
Several groups of workers left the project	Confidence in the project	Due to lack of payment and disagreements, several workgroups quit the project	Contractor		9 days			-
Project works ceased due to financial inconvenients	Economic problems	No economic funds to pay workers	Promoter	Organization	90 days	-		
Misunderstanding about change in delivery date plan	Inadequate communication	Workers were confused about delivery priority of house, as they were not notified about changes in plan			2 days	-		
Poor concrete layer poured on pool floor after landslides ocurred		After landslided occurred, a layer of poor croncrete was applied to prevent accidents	Contractor		-			-
Adapting house to new desing aproved by promoter		Design erros corrected from phase 1 and adapted to phase 2				0.193%		
Work groups did not recive information change of priority in this house		Contractor failed to communicate changes about delivery date and priority			2 days			0.006%
The corners of window and door openings weren't square	Supervision problems	Supervision didn't check if door and window hollows corner's were squared at 90 degrees			-			-
Workers went on strike due to lack of payments after restarting the project	Budget mismanagement	Lack of payments made workers go into strike			12 days			-
Cement and sand supplies late delivery	Late delivery of materials	Supply order was made several days after requested			2 days			-
Late delivery of floor tiles					4 day			-
Plumbing supplies arrived late to project					1 day			-
		Supplier tooked long to ship supplies to project	Supplier		1 day			-
Performance of new workers hired was not productive as expected	Staff continuity	New group of workers had to be hired and trained	Work staff		14 days			-
New excavation on pool area to remove slided earth	Unexpected event	Extra excavation tasks to remove dirt produced by landslide	-		1 day			0.011%

Wrong finishes sealing minon cracks and painting walls	Workmanship errors	Poor finishes on crack repair tasks	Workman	Human	-			0.001%
Correct floor slope on living room area		Workers weren't applying slope on windows sill as ordered			-			0.006%
Old and new workers did not completed scheduled tasks on time	Stress	Workers weren't completing job task at time due to pressure	Work staff		30 days			-
General concern wehter workers would receive payment		Workers were worried due to insecurity on payments	Contractor		-			-
Confussion of workman about promoter's indecision		General uncertainty amgon work staff about promoter indecision	Promoter		-			-

4.3.3.3. House no. 8

In house no. 8 happened the same as house no. 7. Beside the process of adapting it to the new design, all works done were only to complete the esthetic view of the final product. As seen on Table 4.12, the heavy task were related to installing the A/C unit, complete the walls of the pool and installing the iron elements, that replaced the wood elements in previous design.

Table 4.12: House no. 8 construction incidences list.

House no. 8 construction incidences								
Incidence	**Causes**	**Description**	**Responsible**	**Nature**	**Time increase**	**Cost increase**		
						Promoter	**Customer**	**Contractor**
Rainwater caused landslided in pool excavation	Weather conditions	Pool excavation had no protection and rainwater caused landslide	-	Project	3 days			0.024%
Several groups of workers left the project	Confidence in the project	Due to lack of payment and disagreements, several workgroups quit the project	Contractor		9 days			-
Uncertainty among work staff about project final scope	Uncertainty	Confussion among work groups about promoter's indecision	Promoter		-			-
All works within project were paralyzed	Interruption of project	Disagreements between promoter and contractor due to Promoter's unabilty to make payments			90 days	-		
Backyard area invaded by weed due to lack of maintenance	Deterioration of site	Work site was abandoned with no maintenance			1 day	0.206%		
Change of priority in house final delivering	Project scope modification	Delivery priority was postponed further, without noticing workcrew			6 days	-		
Decision of promoter to delay final delivery		Promoter decided to postopone final delivery			6 days	-		
Pressure to finish all construction tasks before customer visit	Pressure to complete tasks	Promoter wanted to show progress in house construction and presured to finish before customer's visit			-	-		

Project works ceased due to financial inconvenients	Economic problems	No economic funds to pay workers	Promoter	Organization	90 days	-		
Adapting house to new desing aproved by Promoter	Design changes	Design erros corrected from phase 1 and adapted to phase 2	Contractor			0.193%		
Redesing plumbing system on pool		Pool plumbing system had to be redesing to fit on exccavation			5 days			-
Solicitation of new parts for pool plumbing system		As plumb system was redesigned, new parts had to be ordered			1 day			0.012%
Poor concrete layer poured on pool floor after landslides ocurred		After landslided occurred, a layer of poor croncrete was applied to prevent accidents			-			-
The corners of window and door openings weren't square	Supervision problems	Supervision didn't check if door and window hollows corner's were squared at 90 degrees			-			-
Pool excavation measurements blueprints didn't match field measurements	Over reliance on 3-D CAD	On site, pool measures were different as showed on CAD blue prints			3 days			0.028%
Work groups did not recive information about priority change of house 8	Inadequate communication	Workers didn't receive any information about priority changes on house delivery			2 days			0.006%
Workers went on strike due to lack of payments after restarting the project	Budget mismanagement	Lack of payments made workers go into strike			12 days			-
Cement and sand supplies late delivery	Late delivery of materials	Supply order was made several days after requested			2 days			-
Late delivery of floor tiles					4 day			-
Plumbing supplies arrived late to project		Supplier tooked long to ship supplies to project	Supplier		1 day			-
Performance of new workers hired was not productive as expected	Staff continuity	New group of workers had to be hired and trained	Work staff		14 days			-
Window's frame didn't fit on wall hollow	Workmanship errors	Window's hollow corners weren't squared and had bad finishes	Workman	Human	-			-
Wrong finishes sealing minon cracks and painting walls		Poor finishes on crack repair tasks			-			0.001%
Correct floor slope on living room area		Workers weren't applying slope on windows sill as ordered			-			0.006%
Old and new workers did not completed scheduled tasks on time	Stress	Workers weren't completing job task at time due to pressure	Work staff		30 days			-
General concern wehter workers would receive payment		Workers were worried due to insecurity on payments	Contractor		-			-

4.3.3.4. House no. 10 (Aggregate and supplies warehouse)

As this house wasn't sold yet, the decision was taken between contractor and promoter for using it as a warehouse to store electrical supplies, bags of cement and lime and aggregate to keep it dry, away from the rain and moist. The incidences that happened in this villa are listed on Table 4.13, basically were related to bad execution and mismanagement from helpers whom were in charge of organizing the incoming supplies.

Table 4.13: House no. 10 construction incidences list.

House no. 10 Warehouse 1 construction incidences							
Incidence	**Causes**	**Description**	**Responsible**	**Nature**	**Time increase**	**Cost increase**	
						Promoter	**Contractor**
House area was covered in weed and dirt	Deterioration of site	Area was neglected and with lack of maintenance	Promoter	Project	9 days		-
All works within project were paralyzed	Interruption of project	Disagreements between promoter and contractor due to to lack of payments			90 days	-	
Several work tools were stolen from storage room	Theft and vandalism	Thiefs broke into storage room stealing work tools	Third party		-		0.027%
Cement stored in warehouse got wet and ruined	Weather problems	Cement bags weren't stored coorectly and rainwater ruined it	Workman		1 day		0.013%
Differential settlements on foundations	Unexpected event	Mild earthquake caused dfferential settlements in house foundations	-	Organization	-		
Cement bags got wet inside warehouse	Workmanship errors	Cement not stored correctly in warehouse got wet	Workman	Human	1 day		0.013%

4.3.3.5. House no. 11

This house was on a intermediate level of priority, and several tasks were on a rush, such as A/C installation with pipelines for water exit, floor and wall tiles placement and adapting the house to new approved design. After that, the house seemed stalled because the rest of tasks were performed with less of a rush.

Besides, the owner was never present to request modifications or at least pay a visit to appreciate the progress of construction on his house. All these reasons influenced on the decline of priority of work progress. Table 4.14 shows all incidences related to construction stage on house no. 11.

Table 4.14: House no. 11 construction incidences list.

House no. 11 construction incidences								
Incidence	**Causes**	**Description**	**Responsible**	**Nature**	**Time increase**	**Cost increase**		
						Promoter	**Customer**	**Contractor**
Uncertainty among work staff about project final scope	Uncertainty	Confussion among work groups about promoter's indecision	Promoter	Project	-			-
Final delivery date postponed several times		Promoter was undecided about final delivery date			12 days	-		
All works within project were paralyzed	Interruption of project	Disagreements between promoter and contractor due to promoter's unabilty to deliver payments			90 days	-		
Rainwater caused landslided in pool excavation	Weather problems	Pool excavation had no protection and rainwater caused landslide	-		3 days			0.024%
Several groups of workers left the project	Confidence in the project	Due to lack of payment and disagreements, several workgroups quit the project	Contractor		9 days			-
Project works ceased due to financial inconvenients	Economic problems	No economic funds to pay workers	Promoter	Organization	90 days	-		
Adapting house to new desing aproved by promoter	Design changes	Design erros corrected from phase 1 and adapted to phase 2	Contractor			0.193%		
Redesign pool 's plumbing system.		Pool plumbing system had to be redesing to fit on exccavation			5 days			-
Solicitation of new parts for pool plumbing system		As plumb system was redesigned, new parts had to be ordered			1 day			0.012%
Poor concrete layer poured on pool floor after landslides ocurred		After landslided occurred, a layer of poor croncrete was applied to prevent accidents			-			-
Pool excavation measurements blueprints didn't match field measurements	Over reliance on 3-D CAD	On site, pool measures were different as showed on CAD blue prints			3 days			0.028%
Workers went on strike due to lack of payments after restarting the project	Budget mismanagement	Lack of payments made workers go into strike			12 days			-
Cement and sand supplies late delivery	Late delivery of materials	Supply order was made several days after requested			2 days			-
Late delivery of floor tiles					4 day			-
Plumbing supplies arrived late to project					1 day			-
		Supplier tooked long to ship supplies to project			1 day			-
The corners of window and door openings weren't square	Supervision problems	Supervision didn't check if door and window hollows corner's were squared at 90 degrees			-			-
Performance of new workers hired was not productive as expected	Staff continuity	New group of workers had to be hired and trained	Work staff		14 days			-
Stock floor and wall tiles model ran out of existences	Resourcing and planning problems	Supplier ran out of existence floor and wall tiles model	Supplier		12 days			-

Wrong finishes sealing minon cracks and painting walls	Workermanship errors	Poor finishes on crack repair tasks	Workman	Human	-			0.001%
Old and new workers did not completed scheduled tasks on time	Stress	Workers weren't completing job task at time due to pressure	Work staff		30 days			-
General concern wehter workers would receive payment		Workers were worried due to insecurity on payments	Contractor		-			-
Workers lack of focus on performing tasks		Confussion among work groups due to promoter's indecision	Promoter		-			-

4.3.3.6. House no. 14

This house was the first one to be handed to the owner. All incidences that occurred here were the example and guidelines on how to build the houses. After this house's design was conceived completely, it served as a model to imitate and build the rest of the houses.

There was a lot of pressure and expectation to complete this house while finishing all details. Stress and pressure to finish works took over all workers and contractor himself, leading into several incidences that had to be repaired on the run. Table 4.15 shows all the incidences that happened during the construction phase final delivery stage of this villa.

Table 4.15: House no. 14 construction incidences list.

House no. 14 construction incidences								
Incidence	**Causes**	**Description**	**Responsible**	**Nature**	**Time increase**	**Cost increase**		
						Promoter	**Customer**	**Contractor**
Final delivery date was advanced days before expected	Pressure to complete taks	Delivery date to hand house to customer was moved days before planned	Promoter	Project	-	-		
Change of priority in house final delivering	Project scope modification	Priority on this house was changed to high priority			6 days	-		
All works within project were paralyzed	Interruption of project	Disagreements between promoter and contractor due to lack of payments			90 days	-		
Several groups of workers left the project	Confidence in the project	Due to lack of payment and disagreements, several workgroups quit the project	Contractor		9 days			-
External paint removed by rain	Weather problems	External paint on entrance area peeled off after rainy day	-		1 day			0.001%
Bathroom toilet plumbing was clogged after installation	Theft and vandalism	Bathroom toilet was clogged after installation	Worker		-			-
Unexpected visit from customer	Visits from customer	Surprise visits from customer soliciting new modifications	Customer		-	-		
Wooden deck floor above main entrance area	Modification solicited by customer	Wood deck above entrance for second living room			-		0.046%	
Extra A/C unit solicited		Extra A/C unit, with ducteries and electric installation solicited by customer			-		0.077%	

Cement and sand supplies late delivery	Late delivery of materials	Supplier didn't shipped order on time	Supplier	Organization	2 days			-
Late delivery of floor tiles		Supplier tooked long to ship supplies to project			4 day			-
Supplier ran out of existence floor and wall	Resourcing and planning problems	Tile model out of stock in supplier warehouse			30 days			-
Different groups couldn't work at the same time on same place		Different workgroups working in the same area damaged each other works	Contractor		5 days			-
Wood floor finish protection had to be reapplied a second time		Work was done on the wrong date and work staff ruined task			1 day			
Team works were ruining each other tasks	Work staff clash	Several work groups working on the same area caused each other to ruin their jobs			-			-
Readapt water exit line from AC unit through external front wall	Design changes	A/C water exit line was better placed trhough external wall			2 days			0.019%
Poor concrete layer poured on pool floor after landslides ocurred		After landslided occurred, a layer of poor croncrete was applied to prevent accidents			-			-
Adapting house to new desing aproved by promoter		Design erros corrected from phase 1 and adapted to phase 2				0.193%		
Window's frame didn't fit in wall holes	Supervision problems	Supervision didn't check if door and window hollows corner's were squared at 90 degrees			-			
The corners of window and door openings weren't square					-			-
Floor tiles in living room area had inverted slope and had to be replaced		Supervision didn't check slope after workwers finished job			2 days			0.001%
Workers went on strike due to lack of payments after restarting the	Budget mismanagement	Lack of payments made workers go into strike			12 days			-
Performance of new workers hired was not productive as expected	Staff continuity	New group of workers had to be hired and trained	Previous work staff		14 days			-
Delay on approveing customer's modifications	Promoter's resolution time	Promoter took long to approve customer's modifications	Promoter		10 days	-		
Delay on payment to landscapping workgroup		Landscapping workcrew didn't recevied payment on time			-	-		
Delay on approve contractor payment		Contractor didn't receive funds to execute payments to workers						
Project works ceased due to financial	Economic problems	No economic funds to pay workers			90 days	-		

Old and new workers did not completed scheduled tasks on time	Stress	Workers weren't completing job task at time due to pressure	Work staff	Human	30 days			-
General concern wehter workers would receive payment		Workers were worried due to insecurity on payments	Contractor		-			-
Workmen couldn't focus on completing their asigned tasks		Uncertainty on final delivery date made workers get anxious	Promoter		-			-
Final delivery date undecided	Distribution of wrong information	Workers were not shure about final delivery date			-			-
Finishing task on walls were not properly done	Omission of checks	workers did a rush job and didn't perform a final check	Worker		1 day			-
External door wasn't installed correctly	Workmanship errors	External doors on main room were not installed correctly	Door installer		3 days			0.001%
Lack of precision from paintor in roof details		Paintor's skill weren't as expected	Worker		3 days			-
Wrong finishes sealing minon cracks and painting walls					-			0.001%
Sealer applied on external wall was washed in rainy day		Workman applied internal sealer on external wall and it peeled of in rainy day			-			0.001%

4.3.3.7. House no. 15

This was the second house on the priority list to be delivered to owner's hands. Same as house no. 14, these two villas were constructed almost simultaneously, but always paying attention on the incidences resolved in the first one to avoid repeating the same mistakes all over again. The delivering process was not as stressful as the previous house, and the entire crew just knew exactly what it to be done to complete the house, always avoiding to repeat the same incidences with the purpose of not wasting time. Table 4.16 present the list of incidences related to the construction phase on this villa.

Table 4.16: House no. 15 construction incidences list.

House no. 15 construction incidences								
Incidence	**Causes**	**Description**	**Responsible**	**Nature**	**Time increase**	**Cost increase**		
						Promoter	**Customer**	**Contractor**
Final delivery date was advanced days before expected	Pressure to complete taks	Delivery date to hand house to customer was moved days before planned	Promoter	Project	-	-		
All works within project were paralyzed	Interruption of project	Disagreements between Promoter and contractor due to promoter's unabilty to make payments			90 days	-		
Wood stair top surface and floor tiles on second floor heights didn't match	Inadequate interface between contractors	Wood stair top surface height didn't match with floor tiles on second floor	Contractor		1 day			
Several groups of workers left the project	Confidence in the project	Due to lack of payment and disagreements, several workgroups quit the project			9 days			-
Unexpected visit from customer	Visits from customer	Surprise visits from customer soliciting new modifications	Customer		-	-		
Wooden deck floor above main entrance area	Modification solicited by customer	Wood deck above entrance for second living room	Customer		-		0.046%	

Watercoating protection materials for roof didn't arrive on expected date	Late delivery of materials	Supplier didn't shipped order on time			4 days			-
Cement and sand supplies late delivery					2 days			-
Late delivery of floor tiles		Supplier had transportation troubles to send the supply order			4 day			-
Supplier ran out of existence floor and wall tiles model	Resourcing and planning problems	Tile model out of stock in supplier warehouse			30 days			-
Different groups couldn't work at the same time on same place		Different workgroups working in the same area damaged each other works	Contractor		5 days			-
Wood floor finish protection had to be reapplied a second time		Work was done on the wrong date and work staff ruined task			1 day			
Team works were ruining each other tasks	Work staff clash	Several work groups working on the same area caused each other to ruin their jobs			-			-
Readapt water exit line from AC unit through external front wall	Design changes	A/C water exit line was better placed trhough external wall			2 days			0.019%
Poor concrete layer poured on pool floor after landslides ocurred		After landslided occurred, a layer of poor croncrete was applied to prevent accidents			-			-
Adapting house to new desing aproved by promoter		Design erros corrected from phase 1 and adapted to phase 2				0.193%		
External paint on entrance area peeled off after rainy day	Supervision problems	Supervision didn't notify worker to use external paint with water protection			1 day			-
Windows frame didn't fit in wall holes		Supervision didn't check if door and window hollows corner's were squared at 90 degrees			-			
The corners of window and door openings weren't square					-			-
Floor tiles in living room area had inverted slope and had to be replaced		Supervision didn't check slope after workers finished their job			2 days			0.001%
Workers went on strike due to lack of payments after restarting the project	Budget mismanagement	Lack of payments made workers go into strike			12 days			-
Performance of new workers hired was not productive as expected	Staff continuity	New group of workers had to be hired and trained	Previous work staff		14 days			-
Delay on payment to landscapping workgroup	Promoter's resolution time	Landscapping workcrew didn't recevied payment on time	Promoter		-	-		
Delay on approve contractor payment		Contractor didn't receive funds to execute payments to workers						
Project works ceased due to financial inconvenients	Economic problems	No economic funds to pay workers			90 days	-		

Floor wood top on stair got wet and damaged	Omission of check	Stair's window not sealed correctly allowing water to enter and damaged floor wood top	Workman	Human				0.001%
Slopiness on paint detail	Workmanship errors	Lack of precision from paintor while painting roof details			2 days			-
Bad finish on sealing wall cracks		Wrong finishes sealing minon cracks and painting walls			-			-
Paint on wall was washed out by rain		Workman applied internal sealer on external wall and rainy washed out			-			-
Steel rod felt out of place		Workman didn't applied adherent product to structural steel rod in wall			-			0.001%
Kitchen stove crystal was broked down		Workman dropped his tool over the stove			-			-
External door wasn't installed correctly		External doors on main room wasn't correctly installed	Door installer		3 days			0.001%
Workers were confused about final delivery date	Distribution of wrong information	Wrong date of delivery was spreaded among workstaff	Work staff		-			-
Old and new workers did not completed scheduled tasks on time	Stress	Workers weren't completing job task at time due to pressure			30 days			-
Workers were worried due to insecurity on payments		General concern whether workers would receive payment	Contractor		-			-
Workmen couldn't focus on completing their asigned tasks		Uncertainty on final delivery date made workers get anxious	Promoter		-			-

4.3.3.8. House no. 16

Similar situation to house no. 10, this villa was used as a second warehouse to storage all wood elements such as doors and all its components, closet doors and draws, and supplies and materials to make all detailed elements in wall corners, roof, etc. Table 4.17 list all incidences related to this house.

Table 4.17: House no. 16 construction incidence list.

House no. 16 Warehouse 2 construction incidences							
Incidence	Causes	Description	Responsible	Nature	Time increase	Cost increase	
						Promoter	Contractor
Cleaning larger areas from weed and dirt	Deterioration of site	Area was neglected and with lack of maintenance	Promoter	Project	3 days		-
All works within project were paralyzed	Interruption of project	Disagreements between promoter and contractor due to lack of payments			90 days	-	
Wood closet doors got damaged	Weather problems	Rainwater enterd in warehouse and damaged doors	-		-		0.002%
Several closet doors were damaged and had missing pieces	Theft and vandalism	Third party broke into warehouse and stole several supplies	Third party				0.001%
Helpers stocked wood doors in a desorganized way	Workmanship errors	Helpers storaged doors in a disorganized manner	Contractor	Human	2 days		-

4.3.3.9. Guardhouse entrance booth

Guardhouse entrance is the access point were the security guard allows visitors and customers entering into the project. During construction phase It had several problems with water leaking through the roof, but as this structure was not a priority to deliver, there was no hurry to repair the roof and finish all necessary facilities. Table 4.18 present the incidences occurred during the construction of the entrance booth.

Table 4.18: Guardhouse entrance boot construction incidences list

Entrance booth construction incidences							
Incidence	Causes	Description	Responsible	Nature	Time increase	Cost increase	
						Promoter	Contractor
All works within project were paralyzed	Interruption of project	Disagreements between promoter and contractor due to lack of payments	Promoter	Project	90 days	-	
Delay on delivering bathroom elements	Late delivery of materials	Supplier delivered late bathroom elements order	Supplier	Organization	1 day		-
Missing paint to complete painting walls	Resourcing and planning problems	There was not enough paint to complete task	Contractor		-		-

4.3.3.10. Incidences that affected the project entirely

Table 4.19 encompass all the incidences that were recurrent and happened within the entire project, both phase One and Two. These incidents have the particularity of embracing all kind of situations and equally affecting the develop of every subproject, going from common incidences such as design changing or supplies arriving late, to more deep problems, such as the negative influence of previous contractor with erroneous decisions that compromised the project, or the lack of confidence and uncertainty about the project development and how these factors affected the performance of workers and work progress.

Table 4.19: List of construction incidents on the entire project.

Overall construction incidences in project								
Incidence	**Causes**	**Description**	**Responsible**	**Nature**	**Time increase**	**Cost increase**		
						Promoter	**Customer**	**Contractor**
No information or blue prints when works started	Pressure to start/complete tasks	Hasty start of works with no blueprints in haste of start production	Promoter	Project	9 days	-		
Promoter insecurity about taking final decisions influenced the behavior of the work staff	Uncertainty	Promoter hesitated about taking decisions of the course of project			42 days	0.004%		
New redesign proposals not accepted by Promoter	Budget poorly developed	Promoter didn't agree on new proposal's specifications			12 days			0.002%
House design was changed to a "low maintenece" design	Project scope modification	New design of houses would be maintance free	Contractor		42 days	0.006%		
Previous design of houses was not optimized	Over reliance from promoter in previous contractor	First house design was erratic, disorganized and required high maintenance	Previous designer		-	-		
Information of progress advancement and project situation were held	Concealment of information	Both Promoter and contractor kept information to themselves	Promoter, Contractor		-	-		-
Customers paid unexpected visits	Visits from customers	Customers visiting overmuch and demanding new changes	Customer		15 days			-
Work day lost because site had to be prepared for receiving customers		Worksite had to be clean and prepared to receive customers on their visits						
Project entrance was flooded and works couldn't be performed due to excesive rain	Weather problems	All works had to be ceased because a hurricane flooded the project entrance	-		7 days			
Electric and water service supply interrupted	Interruption of public services	Public services were unreliable and not constant			25 days	-		-

No authorization to work after 5 p.m. and penalyzation obtained for working after authorized hours	Inadequate communication	Promoter failed to communicate with Project's general manager to obtain neccesary permits	Promoter	Organization	9 days	0.002%		
Troubles to get in the project incoming materials					10 days			-
Promoter demanding more progress reports	Unrealistic schedule to complete tasks	Promoter was pressuring for unrealistic deadlines to complete works			21 days			-
Properties titles not available for customers	Promoter's resolution time	Customers were complaining due to lack of house titles			-			0.035%
Constant changes in house design	Design changes	House designs were constantly changing	Promoter, contractor		35 days	0.008%		
Supply quantities not estimated correctly	Budget mismanagement / Supervision problems	Supply quantities to make request weren't exact	Contractor		8 days			
Work staff clash and planning problems	Acceleration	Groups working on same area constantly clashed and ruined each other jobs			-			-
Customer's demands were getting more stricts	Delay time	Late delivery of houses made customers getting more demanding			-			
Works made out of sequence	Resourcing and planning problems	Tasks not planned were made out of sequence ruining other tasks that were planned			20 days			-
Not enough materials to continue working		At times there was not enough materials and supplies to continue working	Contractor, suppliers					
Cement, sand, agregates were delivered several days after requested	Late delivery of materials	Supplies requested weren't on time at worksite	Suppliers		26 days			-
No motivation along the workers and field engineers	Stress	No motivation in the proect to continue working	Contractor	Human	-			-
Not reaching best work performance.	Workers demotivation	Workers were too demotivated to work at best performance			-			-
Project progress gave the appearance of not advancing		Low performance on workers made the project seem stalled			-			-
External windows and door sills with inverted slope		Workman failed to apply slope on windows and doors sills	Workman		-			-
Several task were ruined and had to be done again		Due to workers neglect, some tasks were sloppy and poorly made and had to be done again						
Confusion and misinformation amongst workers doing wrong tasks	Distribution of wrong information	Wrong or outdated information was spreaded among all groups	Work staff		2 days			0.003%

4.3.4. Analysis of incidences

After detecting and breaking down the impact and root cause of every incidence that happened in each house, and also the incidences that affected the project in general, the table shows the summary of incidences occurred both in phase One and Two. Incidences are classified under criteria of grouping them according to Project, Organization or Human nature. (Love & Edwards, 2004)

The main objective of these summary table is to help extract parameters, variables and keywords that affect the amount of rework emerged on site based on the recurrence or importance of incidences. Also, it helps to show how these variables and concepts interact between each other using system dynamics methodology.

Table 4.20 shows the most recurrent incidences that happened during repair stage on phase One houses, that ultimately lead into rework. Each cause might create an incident or several at a time, or instead, an effect could be generated by one or more causes.

Table 4.20: Repair incidence classification according to nature.

		Project					Organization						People		
	House nº	Pressure to start/complete tasks	Weather problems	Third party damages	Extra works	Customer's presence	Promoter's resolution time	Resourcing and planning problems	Inadequate comunication	Economic solvency	Delay time	Work staff clash	Omission of checks	Stress	Workmanship errors
Phase 1	17	x	x		x	x	x	x			x	x			x
	18	x			x	x	x	x	x			x	x		x
	22	x	x		x		x	x	x					x	x
	26	x	x		x	x	x	x	x		x	x	x		x
	Dumpster	x		x				x		x				x	

From this summary table, the most influential incidents that repair stage had in common were:

On first place we have the pressure to start/complete tasks. This factor was present in each sub-project; the constant pressure from Promoter to resolve each house incidence list was overwhelming. At the same time, each customer also pressured contractor to send the work crew and solve all the problems and complaints, so finally they could enjoy their houses.

Sharing the same spot as pressure, on worksite reigned problems with resourcing and planning. As the contactor could never foreseen or expect when was arriving a new complaint from a customer, the situation took him by surprise and planning never worked well. As the houses were already delivered, finding resources to repair these incidences was slightly constraint, as materials were borrowed from phase 2 construction stage.

On second place, incidences that played a leading role in rework's arise were: Extra work with customer presence, promoter's resolution time and workmanship errors.

Even though customer presence didn't happen on every house, this was a decisive factor in the appearance of additional work. Customer's presence overseeing the course of works development posed a source of pressure to workers. Moreover, the customer was in a position to request any changes he may wish to make, regardless if it was in the original scope of work. For him, it was just one more little task. For the contractor was modifying the entire work structure to add this new assignment to repair's general budget.

Any modification that took place on site had to be approved by Promoter, and this kind of decisions regularly took some time. Meanwhile the work team was uncertain of what to do while expecting the final decision. This wasted time represented a delay on delivery dates to complete repair tasks.

Last, but not least, the workers played also an important role in contributing to rework. Any neglect, mistake, customer's property damaged represented an unexpected incidence to be addressed. And having on mind that the customer was upset by having a work crew passing through the house repairing defects that never should happen wasn't a nice image.

Following on, Table 4. 21: Construction incidence classification according to nature.

shows the different causes related only to construction stage, that led into rework. This table group construction errors that happened in both phase 1 and phase 2 houses, including the participation from previous and new contractor respectively. From the summary table shown below, the most influential incidents that repair stage had in common were:

Inadequate economic solvency and budget mismanagement: dragging problems from previous houses delivered caused economic deterioration in the developments of works on the construction phase. This situation was aggravated by the inadequate budget management when allocating material and equipment resources in the different projects. This caused resources and planning problems that leaded into delays, late delivery of works, and consequently rework.

Design changes: Promoter's indecision about adapting the new group of houses to a new free-maintenance improved design cost the project precious time. Adding to this situation the constant visits from customers asking for customizable modifications caused an eternal source of rework.

Project scope modification: as project designs weren't fully conceived and approved, the main scope of the project was under constant change. Also, scope was tightly connected with budget mismanagements and economic viability of the project.

Resourcing and planning problems: with constant modifications and budget mismanagements, resources weren't estimated correctly. This caused a shortage of resources on several occasions, leaving the work crew without supplies to perform scheduled tasks

Interruption of project: not one, but two times the project was completely interrupted for the same reason; economical disagreements between contractor and promoter. On the second time, the economic situation of the project was in a very critic position that the fact of continue working wasn't feasible

Weather conditions: rain, hurricanes, tropical storms posed an impediment to keep working and having to suspend labors for almost a week as the access into the project were repaired. After the storm went away, several tasks had to be redone again, because rain ruined the work previously done and deteriorated the work site.

Stress and workmanship errors: The pressure to finish works provoked to hurry up without the necessary precision of works ending up with repairs and rework. This high pressure kept the workers all stressed and couldn't focus on doing their job correctly. Also, there was a moment in which experienced workers left the job because of lack of payments, and new personnel was hired to continue the project. These new workers lacked the experience and knowledge of the course of the project. Lack of experience and training lead to bad execution, sloppiness on performing delicate tasks and damaging other crew's works.

Omission of checks: if a member of the work staff takes time to check the job he has previously done, the amount of rework would be reduced in large proportion. With the hurry and pressure to continue working, workers left careless defects that could have been fixed on the spot to avoid a thorough inspection looking for defects and flaws. As time constraint to deliver was tight, not having to do a supervision walkthrough is a time and resource saver that helps focusing on next steps.

Supervision problems: if workmanship errors weren't addressed correctly by supervisors, rework augmented proportionally. Although a mistake from a worker is wrong, a supervisor not doing his job right is even a worst problem. On several occasions there were defects that could be corrected on the spot without wasting more resources if supervision had done their job as expected.

Table 4. 21: Construction incidence classification according to nature.

Phase 2										Phase 1					
Gen. Project	Ent. Booth	16	15	14	11	10	8	7	1	26	22	18	17	**House nº**	
x				x			x	x						Project Scope modification	**Project**
x														Over reliance of client in previous contractor	
x														Budget poorly developed	
										x	x	x	x	Incorrect design	
										x	x	x	x	Lack of designs	
		x				x	x	x	x					Deterioration of site	
x			x	x			x							Pressure to intiate and/or complete tasks	
x					x		x	x	x					Uncertainty	
		x		x		x								Theft and vandalism	
x		x		x	x	x	x	x	x					Weather conditions	
		x												Third party damages	
			x	x	x		x	x	x					Confidence in project	
			x	x					x		x		x	Modifications solicited by customer	
	x	x	x	x	x	x	x	x	x	x	x	x	x	Interruption of project	
x														Interruption of public services	
			x											Inadequate interface between contractors	
x			x	x					x					Visits from customers	
x														Concealment of information	
x			x	x	x		x	x	x	x	x	x	x	Supervision problems	**Organization**
x			x	x	x		x		x					Design changes	
						x		x						Unexpected events	
x														Unrealistic schedule to complete tasks	
x														Delay time	
x			x	x					x					Promoter's resolution time	
x			x	x	x		x	x	x	x	x	x	x	Budget mismanagement	
x	x		x	x	x		x	x	x					Late delivery of materials	
			x	x	x		x	x	x					Staff continuity	
					x		x							Over reliance on 3-D CAD	
x	x		x	x	x						x		x	Resourcing and planning problems	
x							x	x						Inadequate comunication	
			x	x										Work staff clash	
			x	x	x		x	x	x					Economic solvency	
x														Acceleration	
x														Work productivity	
x			x	x										Distribution of wrong information	**People**
x			x	x	x		x	x	x	x	x	x	x	Stress	
			x	x						x	x	x	x	Omission of checks	
x		x	x	x	x	x	x	x	x	x	x	x	x	Workmanship problems	

Both list of incidence causes mentioned before would ultimately lead in the creation and conception of two System Dynamics models. Each one represents rework's behavior on each stage. The idea of split both scenarios is because repair and construction incidences might not share the same causes and it's merely important to address both cases from different approaches might be totally different problems.

4.4. Developing and applying System Dynamics to the project

In this section, System Dynamics concepts previously mentioned are applied to link the causes of the incidents occurred in each stage to analyze and observe how they interact among them. At the same time, this technique helps visualizing how certain decisions or situations subsequently cause the appearance or increase of rework, main focus of study in this analysis.

The information present next ahead was integrated and implemented in a generic influence diagram of rework. The arrows that link each variable indicate a place where a cause and effect relationship exists, while the plus (+) or minus (-) sign at the head of each arrow indicates the direction of causality between the variables. On several occasions a reinforcing loop can be spotted indicating rework's feedbacks cycle.

This analysis reveals that no single factor can be used to pinpoint an unique cause that contributed to rework, but multiple causes directly and/or indirectly. As a result, a generic causal model (for construction and repair stage) is created to demonstrate the interdependency that exists between variables. All factors and variables are presented and discussed below explaining the interconnection between them, thus explaining how the model were created.

After isolating and presenting the major causes of incidences and non conformities on each stage, parameters and variables that control the amount of rework on the system are extracted to observe how all these factor interact and affects each other.

On the following images there is a color code to follow to distinguish variables belonging to different classifications of incidents. Color blue belongs to incidences related to Project, red belongs to Organization incidences, and green groups Human nature incidences. The rest of components shown in diagram with no color are meant to be stocks, a component of the method used to create the diagram.

To create the System Dynamics model it was taken into account that dynamic behavior is thought to arise due to the Principle of Accumulation. More precisely, this principle states that all dynamic behavior in the world occurs when flows accumulate in stocks. Stock and Flow method is used to create and simulate the models presented subsequently.

As a final point, a real-time simulation is provided to present the situation that happened on site. The purpose is to show how the model behaves through the course of time and seeing how all the factors that contribute to the growth of rework in the work site act together to form the system. The software "Insight Maker" is going to be used to create the simulations and obtain graphic examples of what happened during the project and how affected rework's final result.

Building a representation of reality consists of different steps. The first and most important is defining the problem's boundaries. Through the conceptualization of the model, the environment surrounding the system can be introduced into the software.

As the "Stock and Flow" technique is applied to create the simulation, it's important to identify the most important stocks that will accumulate the information. At the same time, sources of information that impact the flows, and flows carrying information through these stock levels have to be identified as well.

In order to identify stocks and flows, it's imperative to determine which variables in the system experiencing the problem define its state (its stocks), and which variables define the changes in its state (its flows). That said, the following guidelines can be used to help identify stocks and flows:

- Stocks usually represent nouns and flows usually represent verbs.
- Stocks do not disappear if time is (hypothetically) stopped. Flows do disappear if time is hypothetically stopped.
- Stocks send out information about the state of the system to the rest of components in the system.

Stocks possess four characteristics that are crucial in determining the dynamic behavior of systems. More specifically, stocks have memory, change the time shape of flows, decouple flows and create delays.

The next step is diagramming the model in software, taking into account drawing causal loop diagrams that links the stocks, flows and sources of information. All components need to have their respective equations governing the behavior of the model. Finally, the only thing left is running the model and observe the results. It's imperative to understand that this is an iterative process of trial and error, therefore, there were several verification test carried out to test the sensitivity and accuracy.

Due to lack of time to study further the functionality of the program, all variables were modeled without any unit associated. The problem was the inconsistency of measurement units between measurable variables and those to which they could not be attributed any unit of measure. Several attempts to assign measure units to some abstract factors were performed, but simulation failed to function because there was an incompatibility between units planted in the model.

4.4.1. System Dynamics for repair stage

The S.D. diagram for repair stage has been built directly from incidence causes detected on site. As repair tasks were not as many compared to construction tasks, there is a singular situation involving the customer already living in the house while works were being performed. His constant presence supervising and monitoring the progress of work posed an impediment for work staff to complete works on time.

To explain in more detail the process of conceiving System Dynamics repair diagram, the model is going to be separated in three parts or "loops" for a easier approach to understand the interconnection between variables to understand their existing underlying relationship.

4.4.1.1. Loop no. 1

The first loop, shown on Fig. 4.4, encompass three major stocks, which are "Rework", "Extra repairs" and "Construction errors". These components are affected by the rest of variables shown on Fig. 4.3. The loop encompass how extra repairs can create delays and eventually leads into more construction errors.

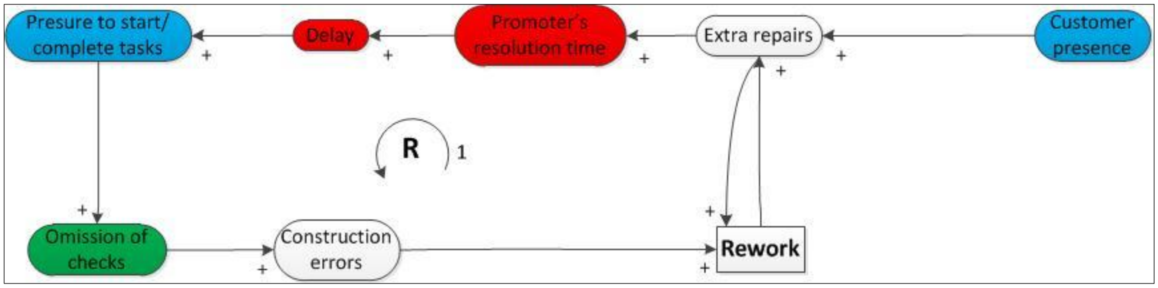

Fig. 4.4: Loop no. 1 S.D. repair model.

The loop starts with the variable **"Presence of customer"**, which impacts directly proportional to **"Extra repairs"**. The behavior of this relationship is similar to a straight line with slope; a greater presence of the customer, more extra repairs will appear.

Following on, the relationship between **"Extra Repairs"** and **"Promoter's resolution time"** is related to an exponential growth. This occurs because the variation over time on the factor "Promoter's resolution time" is proportional to the "Extra repairs" that keep accumulating, which implies a very rapid growth over time. Equally, the variable **"Delay"** is pictured as the 80% of **"Promoter's time"** to approve a decision.

The concept of pressure is a bit hard to imagine, because it has no unit or a way to measure, is a bit of an abstract concept. The way to create this input was based on the idea that a small amount of **"Delay"** didn't caused too much **"Pressure"**. But after a certain point, a considerable amount of delay in works could cause a rapid increase in the amount of pressure in an effort to recover lost time. The idea of introducing "If And Else" function came into picture, and so if the amount of delay was minor to a denominated constraint, the pressure would be low, but if not, then the pressure would be higher.

The more **"Pressure to complete tasks"** directly affected the **"Omission of errors"** proportionally. In site, when there was a lot of pressure to complete certain task or delivery date was getting closer, the amount of errors increased in an uncontrolled way, because there was no time to check and look for mistakes and errors on completed tasks. At the same time, if workers or supervisors didn't stop to look and search for errors in tasks recently done, this accumulated more **"Construction errors"** that had to be done again, leading into rework increase.

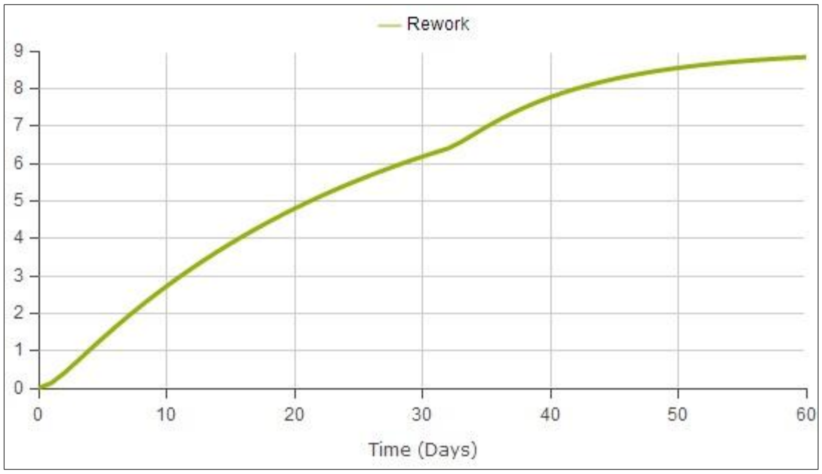

Fig. 4.5: Repair S.D. Loop 1 simulations results.

Following 1st loop description, we have results from the simulator software. In Fig. 4.5, we observe that immediately the loop completes its first cycle, rework immediately appears on scene. This dramatic increase is that in this loop no parameters present to help reduce the amount of rework that was produced. This occurs because the management, to prolong decision-making, as they do not take into account this delay allows the rework is gained without any control.

4.4.1.2. Loop no. 2

The second SD repair loop, exposed in Fig. 4.6, covers how rework generates more work that is not expected nor planned. This unexpected situation demanded more resources and planning to redo activities that were supposed to be perfectly done in the first try. To this situations it has to be added some acceleration to keep up with the schedule and wasting no time, but eventually several teams clashes into each other, causing accidents that need to be addressed quickly, entering once again into Rework stock.

Starting from **"Rework"**, it directly feeds the amount of **"Extra work"** to be redone once again and vice versa. It worked in both ways. **"Extra work"** stock feeds from problems that happened during repair development. Factors like **"Third party damages"** and **"Deterioration of worksite"** posed a great source of extra work expecting to be resolved.

As for **"Deterioration of site"**, factors like **"Weather"** and **"Unexpected problems"** played a leading role affecting the work site. As for unexpected problem, the equation was addressed as a 1.4 times of "weather problems" that affected the course of repairs. And so, these problems deteriorated the worksite directly, affecting all previous works done until that point.

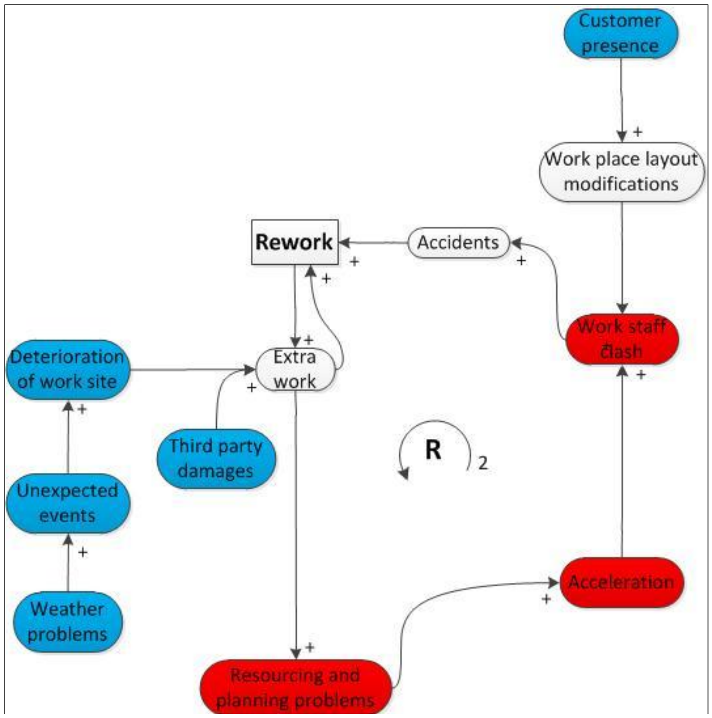

Fig. 4.6: Loop no. 2 S.D. repair model.

At this point, **"Extra work"** generated more **"Resourcing and planning problems"**. Basically, there was a need of more materials and resources to redo activities that were meant to be accomplished on a first try. Planning goes forward and backwards to keep up with everything that's happening, but eventually problems start to accumulate.

To recover lost time, all works had to get **"Accelerated"** to keep up with the schedule planted and tasks start to be made out of sequence in an effort to accomplish as much as possible.

Also it's worth to mention that during repairs, the customer was living in the house, and his constant presence around forced the work team to plan how the work will be made without disturbing the lives of clients. The **"Customer presence"** affected directly the **"Work site Layout"** and planning had to be modified constantly.

Eventually, **"Acceleration"** of tasks and constant modifications on **"Work Layout"** contributed equally, creating chaos in work site and causing work teams to **"Clash"** into each other ruining their works. This situation proportionally affected the amount of **"Accidents"** and damages to customer property. At the end, all these accidents came back to accumulate more rework to be addressed once again.

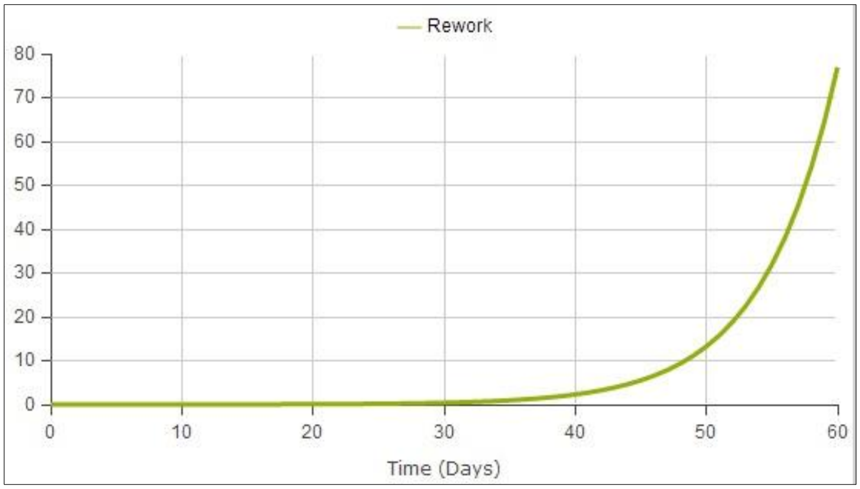

Fig. 4.7: Repair S.D. Loop 2 simulations results.

After modeling this situation, Fig. 4.7 shows that, during the passage of time, routine activities are evolving normally. Occasionally there is an incident that occurred, but, as being something of minor importance, is not properly attended. Although it can't be fully appreciated, during the first 30 days, changes in rework behavior are very discrete and subtle, but silently accumulating. This behavior continues until a moment at which all unaddressed incidents converge in a sudden increase of rework on site.

4.4.1.3. Loop no. 3

The final loop of this model, shown on Fig. 4.8, basically present the path in which rework produces more extra work, eventually leading into committing more construction errors. Loop starts in the same way as Loop 2 mentioned before. Rework increases the amount of "Extra work" to be addressed and this, directly generates more "Resourcing and planning problems.

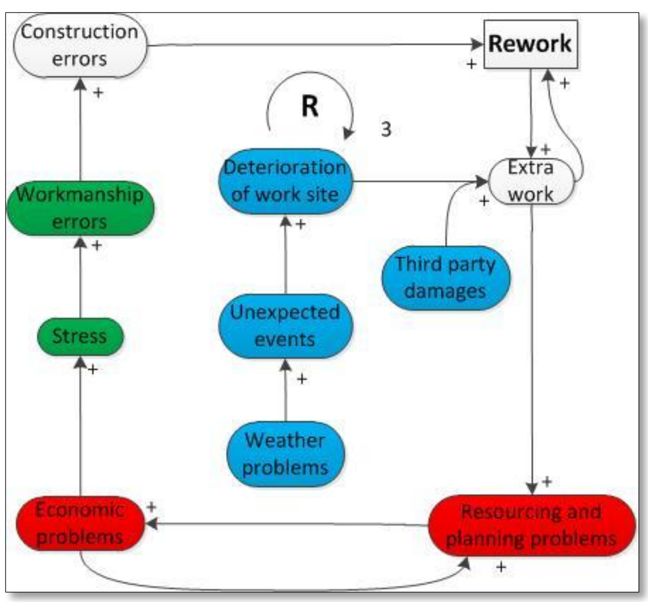

Fig. 4.8: Loop no. 3 S.D. repair model.

Loop start is the same as Loop 2 mentioned before. **"Rework"** increases the amount of **"Extra work"** to be addressed and directly generates more **"Resourcing and planning problems"**. At this point, **"Resourcing and planning problems"** poses a threat into the economic viability of the project. For this case, **"Economic problems"** is addressed as a 55% of **"Resourcing and planning problems"**. At the same time, **"Economic** problems" also increase the problems related to **"Resourcing and Planning"**.

From this instant, the **"Economic"** aspect represents a serious deal when affects workers payments. The uncertainty of not knowing if they will be remunerated for the job they are doing increases the **"Stress"** exponentially.

A worker under **"Stress"** can't focus well on the activities he's performing. This situation increases directly the amount of **"Errors"** and mistakes committed by workers. At the same time, these errors are translated into a direct increase of "Construction Errors" and poorly performed tasks. At the end construction errors only increase the amount of rework to be addressed and corrected.

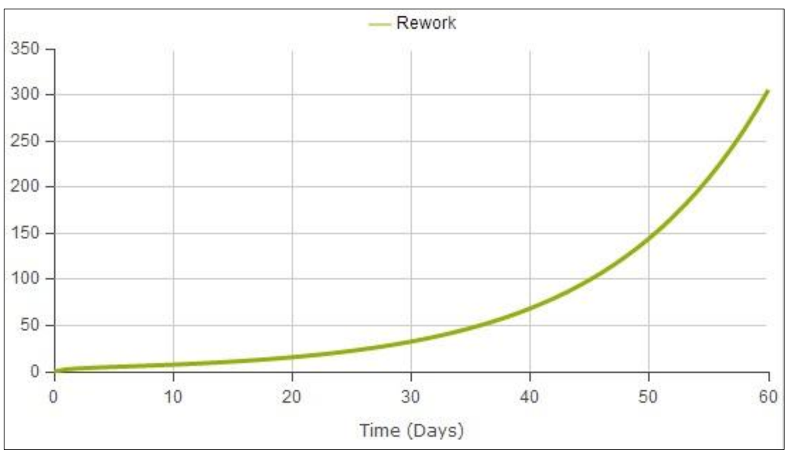

Fig. 4.9: Repair S.D. Loop 2 simulations results.

All components in third loop only contribute in increasing exponentially the amount of rework produced on site. As it can be appreciated on Fig. 4.9, as the loop accomplish its first cycle through, rework starts to accumulate, slowly at first steps. The reason rework quietly begins to grow is because, if there are few issues that resolve, they could be addressed n no time. But, as construction errors keep accumulate it becomes more complex to solve these defects along the march. After 20 days, the graph begins to grow exponentially. Unattended problems keep generating new problems, as every time, the loop complete its cycle.

4.4.1.4. Global S.D. for repair stage

After seeing how these loops interact between each others, the final step is assembling all parts together into one general model presented on Fig. 4.10. The S.D. diagram represents the flow path that increases rework through errors, extra repairs, unexpected situations and the presence of customers while workers were performing their jobs.

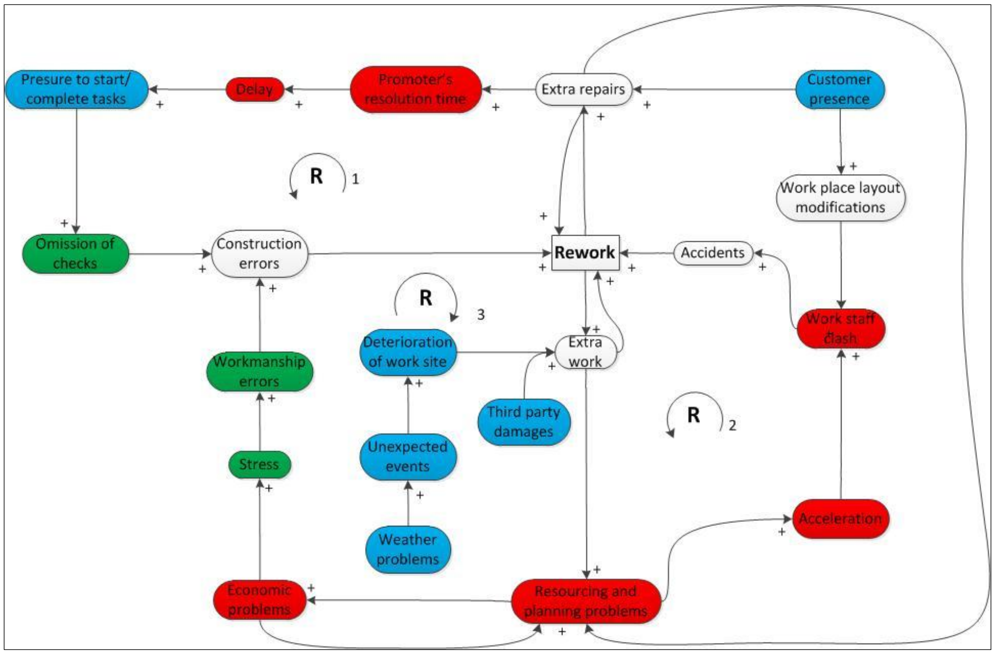

Fig. 4.10: System Dynamics diagram for repair stage.

When all loops are combined into a general system, the way variables interact among them leads to a modification in the general behavior. As seen on Fig. 4.11, the final result is a combination of all three loops.

On the image it can be seen that the behavior of the overall rework repair begins with an exponential growth for the first 15 days, but then the performance curve undergoes a change in slope, which indicates a slight progressive reduction in the amount of rework produced during repairs. This occurs because, on repair stage, there aren't many factors that influence on the supply of new incidents to pile up new task that need rework, so the feedback loop is progressively reduced to reach an "apparent" stability, but maintaining the "quantity" of rework over time, until this situation is properly corrected.

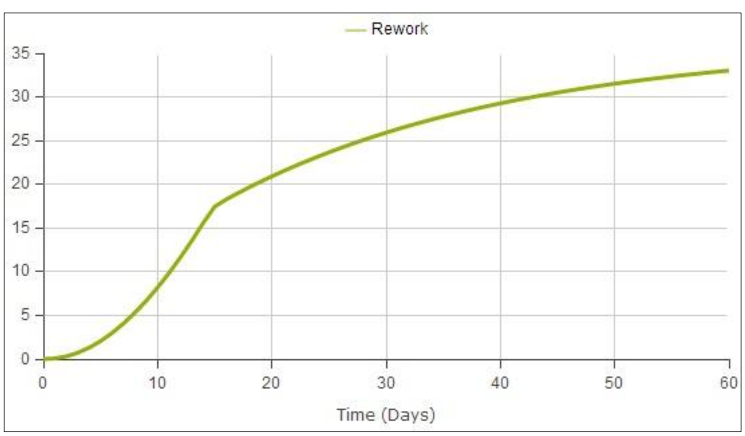

Fig. 4.11: Rework S.D. for repair stage

4.4.2. System dynamics model for construction stage CHECK

In this section is described how construction incidences behave and evolved until rework's arise on site. This stage tends to be more complex than repair stage. Now there are more factors involved controlling rework's outcome. Same as on repair stage, S.D. diagram has been built directly from incidence causes detected on site. The general idea starts at the same point with the same concept, but with some subtle differences.

On this moment, factors such as design changes, scope modifications, uncertainty, etc. come into picture. These variables present a new challenge for the contractor and the promoter, as now there are more problems to address, and almost no time to think well on how decisions taken would affect the project eventually.

The S.D. diagram is composed by three major loops that aim to group al situations and problems, capturing the essence of what really happened during the project. The approach intends to be as close to reality as possible.

4.4.2.1. Loop no. 1

The first loop, shown on Fig. 4.12 mainly exposes how changes from different sources affect the final product. Each change or modification would ultimately lead into rework's increase. These changes were mostly solicited by customer or promoter, or if there was an error on blueprints and modifications were in order to improve the final product. The stocks participating in this loop are "Rework" and "Construction errors".

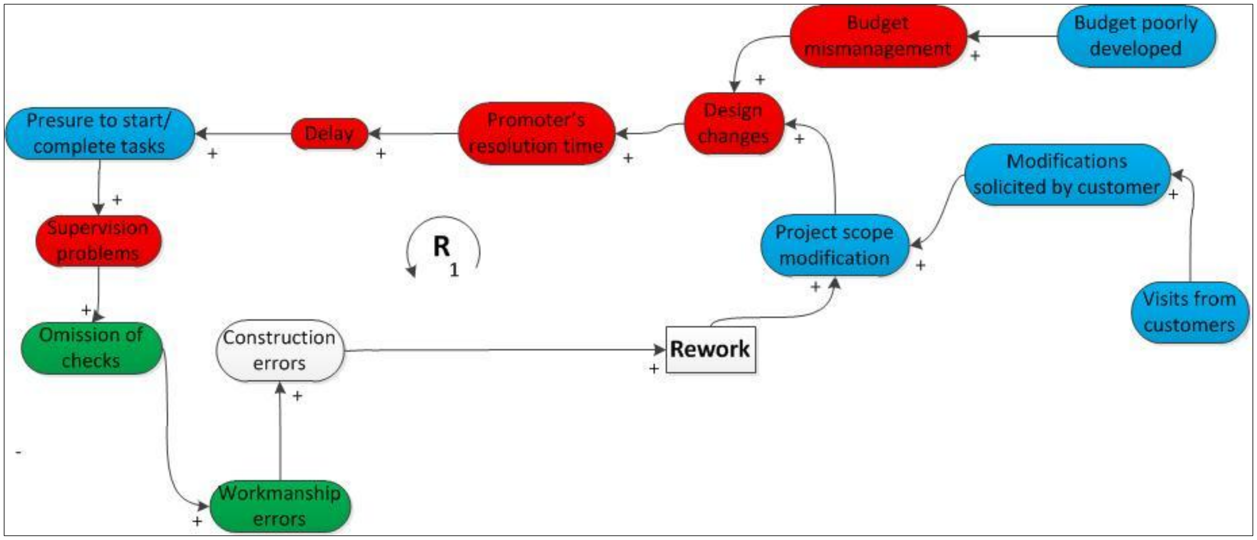

Fig. 4.12: Loop no. 1 S.D. construction model.

The loop starts with **"Customer's surprise visits"** to the project and **"Modifications solicited by customers"**. Not every visit from customer meant a new modification, so the variable "Modifications from customers" equation rest as 40% of visits from customers. An easy example is:, from 10 visits of any customer, 4 of this visits was related about soliciting a new modification or adding customizing features to the house.

At the very end, these **"Modifications"** affected directly the **"Scope"** of the project, as in more modifications, more scope modifications.

In same way, **"Budget poorly developed"** increased directly all **"Mismanagements"**, causing several changes on quality, type of material and choices less expensive.

With these two variables explained, **"Design changes"** comes into play. This factor is clearly affected directly from **"Budget Mismanagement"** and **"Scope modification"**. Generally, a scope modification affected only one house design, but changes in budget ultimately affected the entire project. So, changes in design comes to be 40% of Scope modifications and 60% of budget mismanagement.

Moving on, the relationship between **"Design Changes"** and **"Promoter's resolution time"** is related to an exponential growth. This occurs because the variation over time of factor "Promoter's resolution time" is proportional to changes in design that keep accumulating, which implies a very rapid growth over time. Small amount of changes were quickly approved, but when constant changing was accumulating, resolution time from promoters seemed to extend. Following this concept, the variable **"Delay"** is pictured as the 80% of time **"Promoter's time"** to approve a decision.

Same as mentioned on repair stage, the concept of **"Pressure"** is an abstract idea very hard to quantify. The way to create this input was based on the idea that a small amount of delay didn't caused too much pressure. But after a certain point, a considerable amount of **"Delay"** in works could cause a rapid increase in the amount of pressure in an effort to recover lost time. In here, the idea of using the command "If And Else" function also worked. As a result, if the amount of delay was minor to a denominated constraint, the pressure would be low, but if not, then the pressure would be higher.

With the **"Pressure to complete works"** at full capacity, it was expected a tight supervision from contractor looking for any mistake and correct it right away. But, not every people from staff could perform well under pressure. This kind of pressure generated problems with supervisors failing to spot some mistakes. The equation governing the variable **"Supervision problems"** is just a 70% of "Pressure to start/complete tasks".

"Supervision problems" directly affected the **"Omission of checks"** and, subsequently, with omissions came an increase in **"Workmanship errors"**. Last, with an increase or errors from workers, there was a notable increase in **"Construction Errors"**. All these relationship were directly proportional into each other. Finally, the loop is closed when all **"Construction errors"** start directly increasing the amount of **"Rework"** on site.

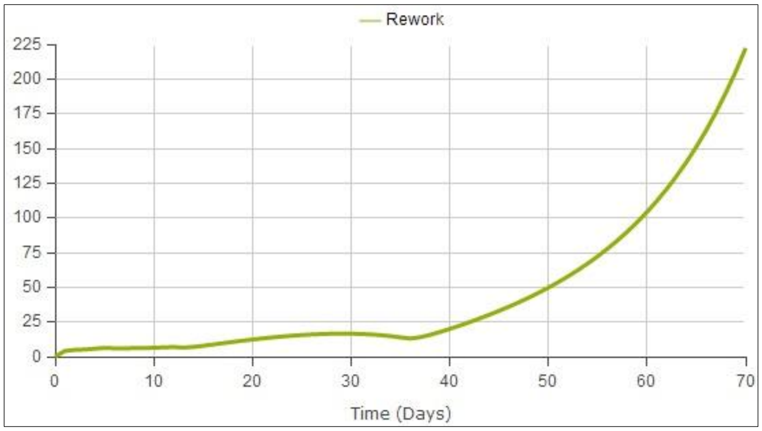

Fig. 4.13: Construction S.D. Loop 1 simulations results.

Fig. 4.13 presents the interaction of variables in the first loop. As it can be seen, Rework tends to accumulate, and then slightly descends until reaching a final up rise. This shifting behavior tends to happens because now we have introduces the role of supervisor and error checks. The purpose of these two variables is to search, discover and correct construction errors found at the moment. But soon after, rework takes over after been accumulating for some time until a certain moment, when it start rising exponentially.

4.4.2.2. Loop no. 2

Fig. 4.14 shows the second loop in construction S.D.. In here, it attempts to cover how rework generates more non-expected work. This situation demanded more resources and planning to redo activities that were supposed to be perfectly done in the first try. To address these circumstances, it has essential to some acceleration to keep up with the schedule and avoiding wasting more time. But eventually several teams clashes into each other, causing accidents that need to be addressed quickly, entering once again into Rework stock.

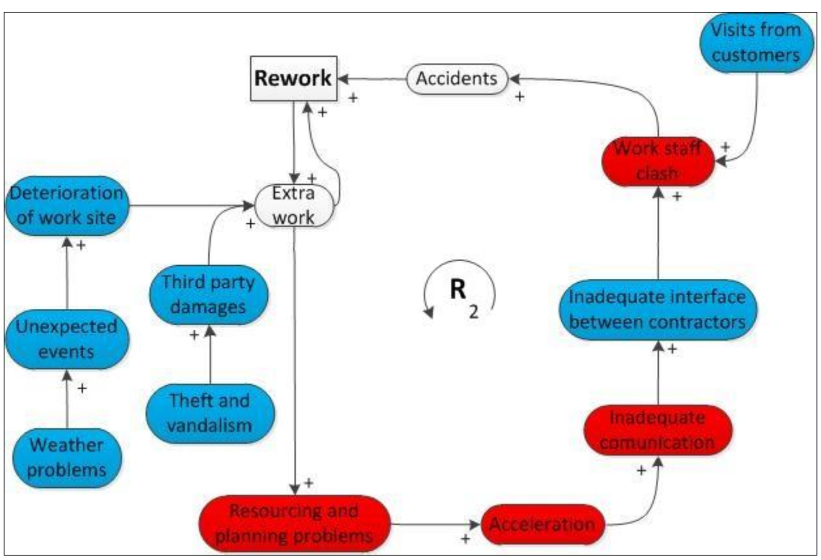

Fig. 4.14: Loop no. 2 S.D. construction model.

Starting from **"Rework"**, it directly feeds the amount of **"Extra work"** to be redone once again and vice versa. It works in both ways. "Extra work" stock feeds from problems that happened during repair development. Factors like **"Third party damages"** and **"Deterioration of worksite"** posed a great source of extra work expected to be resolved.

As for **"Deterioration of site"**, factors like **"Weather"** and **"Unexpected problems"** played a leading role affecting the work site. As for unexpected problem, it was addressed as a 1.6 times of **"Weather problems"** that affected the course of repairs. And so, these problems caused direct **"Deterioration to worksite"**, affecting all previous works done up to that moment.

If there is more **"Extra work",** it generates directly more **"Resourcing and planning problems"**. Basically, there is a need of more materials and resources to redo activities that were meant to be accomplished on a first try. Planning goes forward and backwards to keep up with everything that's happening, but eventually problems started to pile up. To recover lost time, all works had to get directly **"Accelerated"** to keep up with the schedule planted and tasks start to be made out of sequence in an effort to accomplish as much as possible.

Increasing **"Acceleration"** to keep up with schedule slightly affected the **"Communication"** among all teams (around a 30%). The purpose of workers and field engineers was to skip bureaucratic decision-take process and, not wasting time waiting for Contractor or Promoter's approval. Although, due to hurry on completing works and tasks, sometimes there were pieces of information that all team leaders weren't aware, and misinformation was distributed through all teams.

At the same time, the **"Inadequate Communication"** was proportionally direct with the **"Interface between contractors"**. The worst got communications, there was less transferring of information between different contractors.

Customers visits sometimes represented a trouble for proper developments of works. Whenever a customer paid a visit to the project, worksite had to be cleaned and prepared to receive him. This situation was a bit delicate and dangerous. Also, at the same time it was a waste of time and resources to clean the environment. Besides, it was an opportunity for the customer to ask for new modifications or changes.

Along with **"Communication problems"** and adding **"Surprise visits from customers"** to glance work progress, this created a situation of chaos inside the work site and caused work teams to **"Clash"** into each other ruining their works. Through **"Clashes"** and misunderstandings, this proportionally affected the amount of **"Accidents"** and damages occasioned. At the end, all these accidents came back to accumulate more **"Rework"** to be redone once again.

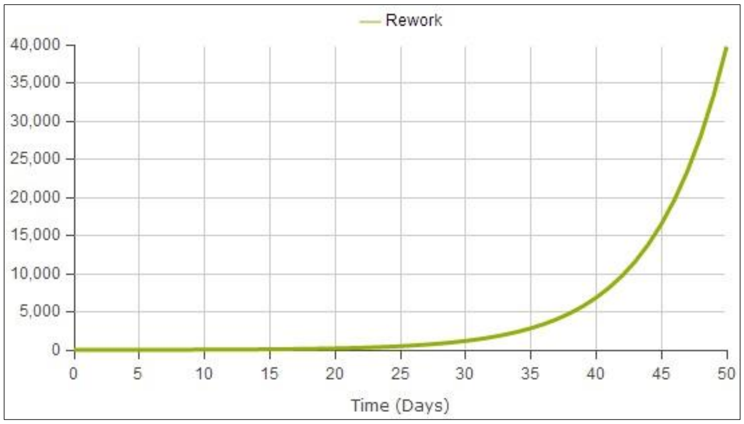

Fig. 4.15: Construction S.D. Loop 2 simulations results.

This loop represents a perfect exponential growth of rework. As there is no variable supervising or controlling variables present, this loop only has factors simultaneously increasing the amount of rework produced, both from external and internal situations. This keeps accumulating until reaching a spot when incidences accumulated generate a chain reaction of new incidences that also need to be addressed and redone. This keeps happening every time the loop completes a cycle.

4.4.2.3. Loop no. 3

The final loop of this model, shown on Fig. 4.16, laid down the path that rework follows from producing more extra work, eventually leading into committing more construction errors. Loop start is the same as Loop 2 mentioned before. **"Rework"** increases the amount of **"Extra work"** to be addressed and directly generates more **"Resourcing and planning problems"**.

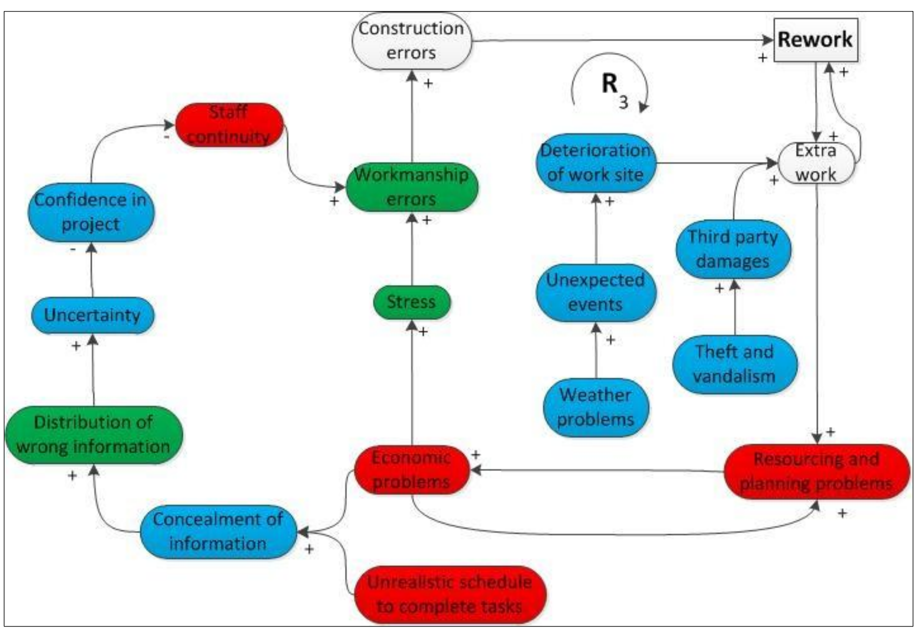

Fig. 4.16: Loop no. 3 S.D. construction model.

At this point, **"Resourcing and planning problems"** poses a threat into the economic viability of the project. For this case, **"Economic problems"** is addressed as a 55% of **"Resourcing and planning problems"**. At the same time, **"Economic** problems" also increase the problems related to **"Resourcing and Planning"**.

At this instant, regarding to construction stage, the **"Economic"** aspect represents a more interesting problem compared to repair stage.

In one hand, if project's **"Economic"** stability is compromised, it will affect and threat directly to workers payments. When a workman is uncertain of not knowing for sure if he will be remunerated for the job he's performing, the level of **"Stress"** increases exponentially. A worker under **"Stress"** can't focus well on the activities he's performing. This situation increases directly the amount of **"Errors"** and mistakes committed by workers. At the same time, these errors are translated into a direct increase of **"Construction Errors"** and poorly performed tasks.

On another hand, the **"Economic stability**" of the project silently increase a dangerous situation. When contractor or promoter know that the general situation is not going well, both parts start to **"Conceal"** information on project's status to cover their faults, with the intention of disguise the reality and avoid future disagreements and disputes.

Another factor that equally contributes on "Concealment" increase is the **"Unrealistic schedules"** proposed by Promoter to deliver works. In an effort to gain time, contractor usually hold information back on what their real schedule is and how much rework they encounter and push downstream. At the end, the variable **"Concealment"** is fed proportionally by the **"Economic problems"** and **"Unrealistic schedules to complete tasks"** planted by promoter.

From this point on, next concepts are influenced proportionally direct from their antecessors. **"Concealment of information"** directly influence in the **"Distribution of incorrect information"** to held the current status of reality. Having occurred this situation, with the incorrect information spread through worksite, workers started to feel **"Uncertain"** about the scope of the project or if the situation is marching correctly. Soon after "Uncertainty" accumulated levels rises up to a certain point, the staff started to lose confidence in the project.

Without **"Confidence"** and security in the project, workers had no reasons to stay in the project anymore. Several teams of experienced men quit the project and work **"Staff"** had to be replaced. This situation was disturbing because these workers knew from end to end the particularities and details of works, also they were trained in their respective duties at a certain point that didn't need help to accomplish their jobs.

These circumstances led the contractor into hiring new workers to continue working. But new employees need to be trained, and get used to the rhythm and pace of works. The period of training and forming these workers supposed a delay in fulfilling established dates of deliveries.

With new work staff, it was expected a direct increase in the amount of "**errors from workers**" due to lack of experience and "Stress". Subsequently, these "Workmanship errors" led directly into more **"Construction errors"** and finally completing the loop with an increase in the amount of "**Rework**" within the project.

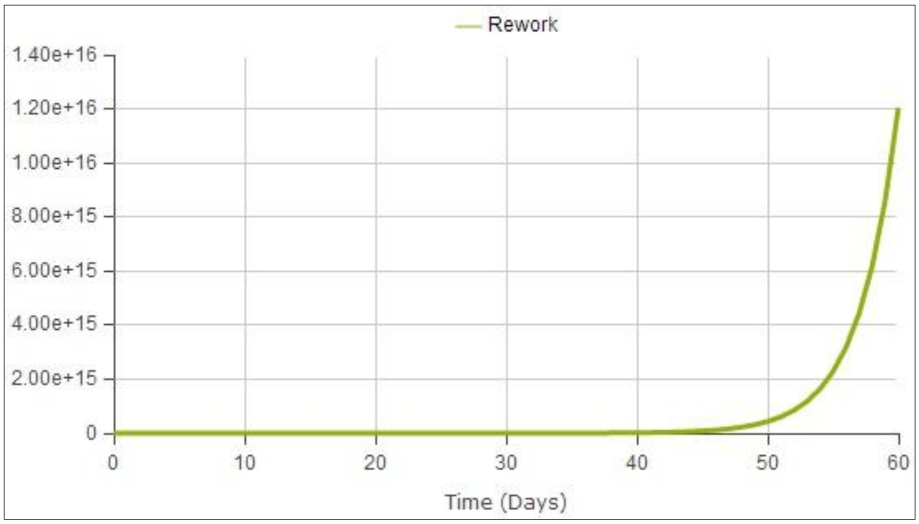

Fig. 4.17: Construction S.D. Loop 3 simulations results.

On Fig. 4.17, rework seems not to increase at all while time pass by. After 45-46 days, suddenly its behavior shifts into a dizzily increase. The reason for this kind of performance lies with the fact that there are more variables affecting the construction errors. Concepts like "Concealment", "Economic troubles" and "Stress" are very harmfull to project's development.

Besides, this loop refers to a change in the working groups, as several workers with experience and knowledge of the project left the job due to lack of confidence and uncertainty about the course of the project. Having to hire new employees resulted in an immediate increase in the number of construction errors due to reasons such as lack of experience and training.

4.4.2.4. Global S.D. for construction stage

After describing the loops that compose the model, is time to bring together all the pieces into a general model presented on Fig. 4.18. After seeing how these loops interact between each others, the final step is assembling all parts together into a universal model. This S.D. diagram represents the flow path that increases rework through errors, extra works, unexpected situations , unexpected visits of customers and more subtle factors such as uncertainty, confidence, change of work staff and lack of experience and training in new workers.

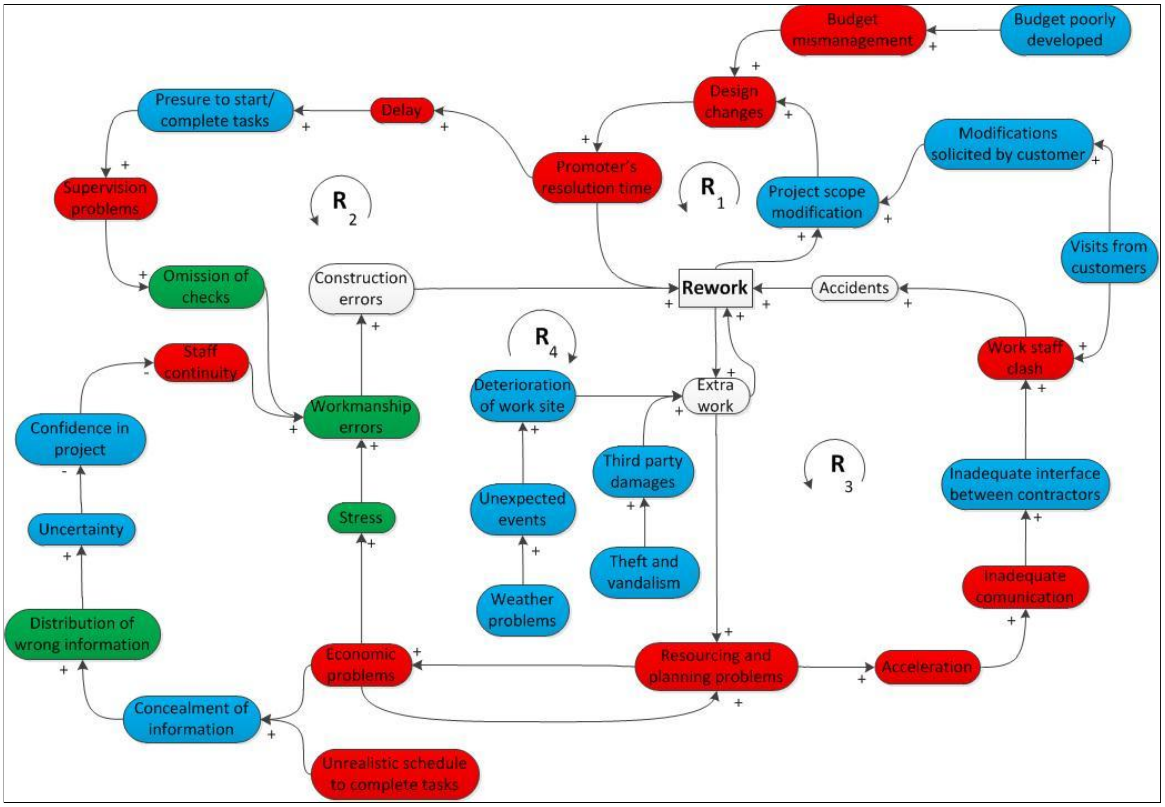

Fig. 4.18: System Dynamics diagram for construction stage.

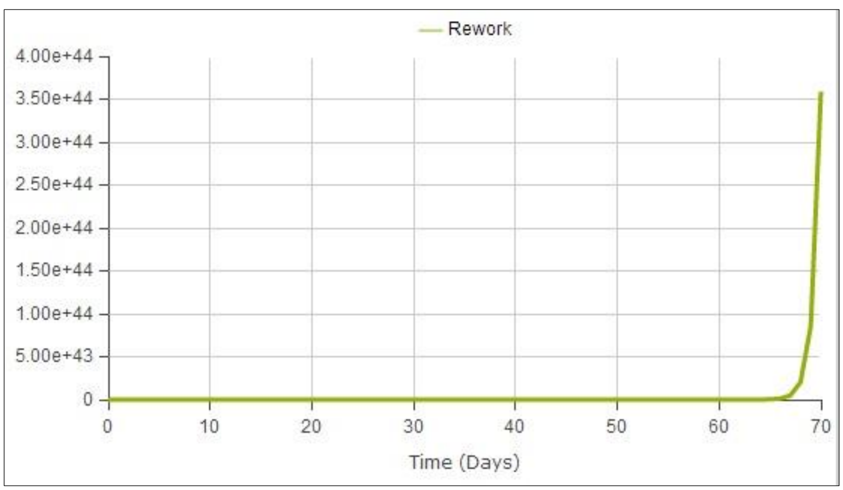

Fig. 4.19: Rework S.D. for construction stage

Assembling together all construction loops into an universal model combines the contribution of each of the parts, to generate the behavioral graph of rework shown on Fig. 4.19. What happened in this image is simply the consequences of not addressing on time the incidences that keep occurring along the course of the project. All variables keep producing incidences and troubles that accumulate in the "Rework Stock" until is too late. The amount of work needed to be redone again is abysmal, resources start to run out, planning to attend all problems gets more complex, economic stability begins to fail, and step by step the project initiate a journey into imminent failure.

5. Chapter 5: Conclusions

This master thesis aimed to present, through a case study, the latent behavior of rework within a construction and repair project. To analyze this case, System Dynamics was used as a tool to establish the relationship between the causes of incidences to examine the way that those factors interacted among them. S.D. also aids to visualize how certain decisions or situations, could cause latent appearance of rework.

Through all the results obtained from simulations, one can conclude and absolute truth: rework phenomenon remains dormant and unnoticed throughout the life of the project, but equally accumulates through the decision-making without long-term thinking, lack of clarity in the objectives to reach and constant design changes due to insecurity or third party intervention, just to mention a few causes.

Having analyzed all the incidences that happened on each house, great sources of rework could be located in an attempt to pin point which incidences generated the most amount of work to be redone once again. On construction stage, major incidents that contributed to increase rework were: Design changes, Scope modifications, concealment of information, uncertainty, stress, economic problems and the constant intervention from customers with surprise visits and soliciting modifications.

On repair stage, the most dangerous factor that affected the course of works was, in fact, the constant presence of owner monitoring the work done. This created an stressful environment for workers to develop their job naturally. The house owner, playing a role of supervisor was constantly looking over the shoulder of workers, who remained worried about committing any mistake. In addition, every whim that crossed the customer's mind was, indeed, a potentially extra work awaiting to happen.

In my personal opinion, even though errors from workmen can lead to rework, if a worker feels that the person in charge of the project doesn't know how to lead and/or doesn't have an idea of where the project is heading, that worker starts to feel disoriented, lost and demotivated. The workman could see that if the manager doesn't have a clue of what's going on in the worksite, then the hole project is surely doomed to failure. Doesn't matter the experience of the workers; if a leader can't lead, then everyone would do as they consider what is "right".

In order to avoid rework arising, it's important to notice that projects evolve in time and that they're dynamic, not a succession of stationary events waiting to happen one after other in a specific order, and that there are other factors present that are more "intuitive" and not meet the eye of the manager at a glance, but only through past experiences it's recognizable that they exist.

Furthermore, the process carried out in this master thesis is not a simple procedure that can be applied immediately on any structure. Systems thinking requires necessarily a process of feedback and learning from mistakes made in past projects. This can ensure the project manager to be prepared before making any decision to be taken in any kind of adverse situation.

It should be noted that the procedure accomplished throughout the entire document would've been impossible to conceive using only traditional planning and control tools. These methods have proved ineffective at providing quick and reliable information. Their tendency to increase in detail has increased their complexity, inhibiting practical strategic analyses.

This approach dispenses with much of the detail required by the traditional tools, but enables modeling of the systemic effects which traditional tools cannot model. In this Master Thesis, it has been applied and developed a conceptual framework in which System Dynamics models are combined with traditional tools providing complementary support, and validated the models in a software simulator.

At the very end, traditional models will always support the project manager in the detailed operational problems within the process. System dynamics models, on another hand, provide more strategic insights and understanding about the effectiveness of different managerial policies. Also provides an alternative view in which the major influences affecting the system are considered and quantified explicitly, regardless if they're abstract or tangible concepts. The two approaches provide complementary support to project management; this suggests it could be of major value to integrate the best of both worlds to resolve any situation. (Bowers & Rodrigues, 1998)

Finally, it's essential to mention that, although the situations mentioned above are part of a project of very specific characteristics, many of these concepts can be extrapolated to other similar types of construction projects. This is mainly because many of the situations that occurred during the execution of the work usually occur within any construction project. One must only verify that certain characteristics and features, such as the country way of working, procurement methods, contract type and method of payment for works performed have some resemblance.

6. References

Abdel-Hamid, T. (1988). "Understanding the 90% syndrome in software project management: A simulation case study". *Journal of Systems Software, no. 8* , 319-330.

Ackermann, F., & Eden, C. (2005). "Using causal mapping with group support system to elicit an understanding of failure in complex projects: some implications for organizational research". *Group Decision and Negotiation, no. 14* , 355-376.

Ackermann, F., Eden, C., & Williams, T. (2005). "Modelling litigation: mixing qualitative and quantitative approaches". *Interaces, no. 27 (2)* , 355-376.

Ackermann, F., Eden, C., & Williams, T. (1997). "Modelling litigation: mixing quialitative and quantitative approaches". *Interfaces, no. 27 (2)* , 48-65.

Baccarini, D. (1996). "The concept of project complexity-a review". *International Journal of Project Management, no. 14 (4)* , 201-204.

Banks, J., Carson, J., Nelson, B., & Nicol, D. (2001). "Discrete-Event System Simulation". *Prentice Hall* , 3.

Barber, P., Sheath, D., Tomkins, C., & Graves, A. (2000). "The cost of quality failures in major civil engineering projects". *International Journal of Quality and Reliability Management, no. 17 (4/5)* , 479-492.

Bellinger, G. (2009). "Insight Maker Manual". *Systems Thinking In Action* .

Bowers, J., & Rodrigues, A. (1998). "System dynamics in project management: a comparative analysis with traditional methods". *System Dynamics Review* .

Burati, J. (1992). "Causes of quality deviations in desgin and construction". *Journal of Construction Engineering and Management, no. 118* , 34-49.

Busby, J., & Hughes, E. (2004). "Projects, pathogens and incubation periods". *International Journal of Project Management, no. 22* , 425-434.

C. Dorf, R. (1999). "The Technology Management Handbook". *CRC Press* , 13-34.

Cooper, K. (1980). "Naval shipyard production: a claim settled and a framework built". *Interfaces, 10 (6)* , 30-36.

Cooper, K. (1993). "The rework cycle: benchmarking for the project manager". *Project Management Journal, no. 24 (1)* , 17-22.

D.L. (2007, 5 14). "Dominican Economy grows 9.1% slightly less than before". *Diario Libre* .

DeMarco, T. (1982). "Controlling software projects: management, measurement and estimation". *Yourdon Press, New York, NY* .

Department of State, U. (2012). *U.S. Relations With the Dominican Republic.*

DGII, R. D. (2008). *"Definición de ITBIS".*

Firedrich, D., Daly, J., & Dick, W. (1987). "Revisions, repairs and rework on large projects". *ASCE Journal of Construction Engineering and Management, no. 113 (3)* , 488-500.

Ford, D. (2003a). "Overcoming the 90% Syndome: Iteration management in concurrent development projects". *Concurrent Engineering, Research and Applications, no. 11 (3)* , 177-186.

Ford, D. (2003b). "The Liar's Club: Concealing Rework in Concurrent Development". *Concurrent Engineering, Research and Applications, no. 11 (3)* , 211-219.

G. Rodriguez, A., & M. Williams, T. (1998). "System Dynamics in Project Management: Assesing the Impacts of Client Behavior on Project Performance". *Journal of the Operational Research Society, Vol. 49 (1)* .

Hirano, H., & Shimbun, N. (1989). "Poka-Yoke: Improving product quality by preventing defects". *Productivity Press, Cambridge. MA.*

Hoedemaker, G., Blackburn, J., & Van Wassenhove, L. (1999). "Limits to concurrency". *Decision Science, no. 30 (1)* , 1-17.

Hoy. (2007, 7 19). "Dominican real estate tourism boom: US$1.5 billion in 2007, US$3.0 billion in 3 years". *Hoy* .

Hwang, B.-G., Thomas, S., Haas, C., & Caldas, H. (2009). "Measuring the impacts of rework on construction cost performance by project characteristics and sources or rework". *ASCE Journal of Construction Engineering and Management* , 187-198.

Kiewel, B. (1998). "Measuring progress in software development". *PM Network, no. 12 (1)* , 29-32.

Library of Congress, U. S. (2007). *"Dominican Republic-Climate Country Studies US".*

Love, P. (2002). "Influence of project type and procurement method on rework cost in building construction projects". *ASCE Journal of Construction, Engineering and Manegement, no. 128 (1)* , 18-29.

Love, P. E., Goh, Y. M., & Han, S. (2010). "Rework in complex offshore projects: The case of oil and gas tension leg platforms". *Cobra 2010* .

Love, P. E., Goh, Y. M., & Han, S. (2010). Rework in complex offshore projects: The case of oil and gas tension leg platforms. *Cobra 2010* .

Love, P., & Edwards, D. (2004). "Forensic project management: the underlying causes of rework in construction projects". *Civil and Environmental Engineering Systems, no. 12 (3)* , 207-228.

Love, P., Edwards, D., & Irani, Z. (2008). "Forensic project management: an exploratory examination of the causal behavior of design-induced error". *IEEE Transactions in Engineering Management, 55(2)* , 234-248.

Love, P., Mandal, P., & Li., H. (1999). "Determining the causal structure of rework influences in construction". *Construction Management and Economics* , 17, 505-517.

Lyneis, J. M., G. Cooper, K., & A. Elsa, S. (2001). "Strategic management of complex projects: a case study using system dynamics". *Syst. Dyn. Rev., no. 17* , 237-260.

Matousek, M., & Schneider, J. (1976). "Untersuchgen zur Struktur des Sicherheitsproblem bei Bauwerken". *Birhäuser, Basel, Switzerland (In German)* .

McConnell, S. (1999). "Brook's Law Repealed". *IEEE Software, no. 16 (6)* , 6-8.

McMaster, G. (2000). "Can we learn from project histories?". *PM Network, no. 14* , 66-67.

Mohapatra, P., & Mandal, P. (1989). "The system dynamics paradigm". *Decision, 16 (4)* , 251-266.

Mohapatra, P., Mandal, P., & Bora, M. (1994). "Introduction to System Dynamics Modeling". *Universities Press, New Delhi, India* .

MOPC. (2005). *"Funciones, Mision y Visión del Ministerio de Obras Públicas".* Santo Domingo.

Ortega, I., & Bisgaard, S. (2000). "Quality improvement in the construction industry: three systematic approached". *Quality and Technology Series, report no. 10, ITEM, University of St. Gallen, Switzerland* .

Oshry, B. (2008). "Seeing Systems: Unlocking the Mysteries of Organizational Life". *Berrett-Koehler* .

Palaneeswaran, E., Love, P., Kumaraswamy, M., & Ng, S. (2008). "Mapping rework causes and effects using artificial neural networks". *Building Research and Information, no. 36 (5)* , 450-465.

Pei-Yin Feng, P. (2009). *"Causes and Effects of Rework on the Delivery of Healthcare Facilities in California".* Berkelee, California.

Robinson-Fayek, A., Dissanayake, M., & Campero, O. (2003). "Measuring and classifying construction rework: a pilot study". *Department of civil and environmental engineering, construction owners association of Alberta, Canada* .

Rodrigues, A., & Bowers, J. (1996). "The role of system dynamics in project management". *International Journal of Project Management* , 213-220.

Rogge, D., Cogliser, C., Alaman, H., & McCormack, S. (2001). "An investigation of field rework in industrial construction". *RR153-11 Construction Industry Institute, Austin Texas* .

Rouse, M. (2012). "IT project management and portfolio management". *WhatIs* .

Standish. (2004). "CHAOS Report". *Report* .

Sterman, J. (2002). "System Dynamics Modeling: Tools for learning in a complex World". *IEEE Engineering Management Review, no. 30 (1)* , 42-52.

Sterman, J. D. (2000). *"Business Dynamics: systems thinking and modeling for a complex world".* McGraw Hill/Irwin.

Terms, G. (2010). *"The Business Continuity Institute Good Practice Guidelines".* Global Edition.

Wiliams, T. (1999). "The need for new paradigms for complex projects". *International Journal of Project Management, Vol. 17* , 269-273.

Wiliams, T. (1999). The need for new paradigms for complex projects. *International Journal of Project Management Vol. 17* , 269-273.

Wiliams, T., Ackermann, F., & Eden, C. (2000). "Structuring a Disruption and Delay Claim". *Working Paper, no. 2000/1. University of Strathclyde Dept. Management Science, Glasgow, U.K.*

Williams, T. (2002). "Modelling Complex Projects". *John Wiley and Sons, Chichester* .

Williams, T., Eden, C., Ackerman, F., & Tait, A. (1996). "Vicious circles of parallelism". *International Journal of Project Management, 13 (3)* , 151-155.

Williams, T., Eden, C., Ackermann, F., & Howick, S. (2001). "The use of project post-mortems". *PMI Seminars & Symposium. Proceedings* .

Williams, T., Eden, C., Ackermann, F., & Tait, A. (1995). "The effects of design changes and delays on project costs". *Journal of Operational Research Society, 46* , 809-818.

Wolstenholme, E. (1990). *"System Enquiry: A System Dynamics Approach".* NY: John Wiley & Sons.