Reducing rework costs in construction projects

Bachelor thesis

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Colophon

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Preface

This document contains the report of my internship at Grupo Willliams (GW) that was conducted to conclude my Bachelor studies of Civil Engineering at the University of Twente. GW is a real-estate and construction company based in Honduras, Central America. GW has several offices around Honduras and their projects mainly consist of residential projects or commercial constructions (shopping malls, offices, warehouses etc). During the last three months I have been working as an intern at their main office in San Pedro Sula, where approximately 50 people work on a daily basis. My research focused on rework costs and events, one of the most frequent failure costs in construction in general. These failure costs tend to be even higher in construction projects in developing countries such as Honduras. The goals of this study were assessing rework costs in GW's projects and suggesting improvements to mitigate rework costs in future projects. The assessment was done through analysis of realized projects. At first a financial analysis was done to determine the amount of rework costs GW is dealing with. To find the causes of the rework events personnel was interviewed. Based on these analyses and information gathered from existing literature recommendations and suggestions for improvement were made. This report contains the results of this research.

This research would not have been possible without the help of some people. First I would like to thank Ir. Jimmy Avendaño Castillo, my supervisor at the University of Twente. He was always willing to provide feedback to my progress and his advice and knowledge were of great assistance. Besides the professional support he also arranged a guest family and my Spanish course. Thanks to the family Flores for making me feel at home even though Honduras is a country totally different from the Netherlands. Also my gratitude goes out to all the employees at GW, especially those who helped me conduct this research, namely Ing. Juan Carlos Molina, Arq. Nelly Paredes, Arq. Mireya Lean, Ing. Dagoberto Palma and Ibeth Raudales. Finally I would like to thank Ing. David Williams and Lic. Evy Williams for giving me the opportunity to conduct my Bachelor thesis at their company.

San Pedro Sula, Honduras, July 2010

Yuri Christiaan Mastenbroek

Summary

In this report the results of the research on rework events in construction projects of Grupo Williams (GW) are presented. The objective of the research has been formulated as: *"To assess rework costs in construction projects of Grupo Williams and suggest improvements to reduce these rework costs."* The assessment was done through analysis of realized projects. At first a financial analysis was done to determine the amount of rework costs GW is dealing with. Secondly, to find the causes of the rework events personnel was interviewed. Based on these analyses and information gathered from existing literature recommendations and suggestions for improvement were made.

Failure costs are all costs that are made unnecessarily to reach the final product. Rework costs are an example of failure costs. Rework has been defined as: *"The unnecessary effort of re-doing a process or activity that was incorrectly implemented the first time."* Rework can have severe consequences, such as cost overruns and time overruns. Besides these direct consequences, there might also be indirect consequences, such as stress, de-motivation or loss of future clients. Rework events can have many different origins and for this research they have been categorized into four categories; changes, errors, omissions and damages.

To assess the gravity of rework costs in GW's projects the financial results of several realized projects have been analyzed. Rework indicators (labour, material, cost, or time overruns and revised contract values) have been studied and from these studies several conclusions were drawn. It was concluded that GW deals with high failure costs, cost overruns of up to 54% were identified and that rework makes up a large part of these cost overruns. Change orders were also very frequent and were found to be the most important cause of rework events.

The causes were further analyzed by interviewing employees. Based on existing literature an extensive list of rework causes was made and during the interviews the interviewees were asked to confirm or deny statements regarding rework causes. The causes that were most frequently confirmed, can be grouped into the understanding categories. 50% of the causes are change-related, 37% is error-related and 13% falls into another category.

- Change orders
- Lack of coordination
- Late material deliveries
- Changes to construction methods
- Personnel-related causes

Knowing what causes rework events is already a step in the good direction. Now improvements have to be introduced to avoid these failures from happening again in future projects. Therefore for all of the mentioned groups improvements have been suggested. Besides implementing these suggestions it is important that GW starts evaluating rework events more properly to adopt inter-project learning. To do this rework events should be reported and processed into a database. A report form and database set-up have therefore been developed. Furthermore has a rework monitoring checklist been made to monitor rework during a project. Another conclusion, that did not regard rework, was that the financial evaluation of projects left much to be desired, that is why it is highly recommended that GW evaluates the processes related to accounting (contabilidad) and balance sheets (presupuestos) in the near future.

Contents

List of tables and illustrations

1 Problem identification

This chapter will introduce the problem, that many construction or real-estate companies deal with, that this research will be about. It is a general problem in the construction business all over the world but the problem tends to be bigger in developing countries. The research objectives will be stated and research questions will be raised in this section as well.

1.1 Problem description

Engineering projects can fail for many reasons. In many real-estate projects total costs exceed the expected costs and because of that the company gains less profit than calculated. In some cases it might even gain no profit at all or even worse, incur losses. These additional costs are often referred to as failure costs. Examples of failure costs are time delay (when deadlines are not reached) and cost overrun. These costs can have many origins such as bad material management, downtime or rework. This research will focus on one specific cause of failure costs, namely rework.

When delivered products do not meet the requirements or expectations, work often has to be redone. Rework occurs in various phases of the construction process or in various divisions of a company. Rework can occur on the construction site or in a management department due to for example bad materials management. The last has already been researched at GW by Ten Klooster (2009). Rework can also have internal or external origins. Changes in clients' expectations are an example of an external factor that might lead to rework. Rework can cause many costs to be higher than calculated at the start of the project.

Previous studies by P.P.A. Zanen(Zanen, 2008) and M. ten Klooster (ten Klooster, 2009) have proven that the problems stated above are also reality for GW. P.P.A. Zanen states that the quality of the deliverables, in this case houses, is determined based on functionality and aesthetics. This means that everything in the house should work, such as electricity and water, once it is delivered and that the finishings such as paint, doors, windows and ornaments should be to the client's satisfaction. Quality of work is verified by regular inspections of the project's supervisor. Unfortunately the quality is not always as desired and work has to be redone, which has a negative effect on the project schedule and costs (Zanen, 2008).

1.2 Research objective

Based on the problem description a research objective and research questions can be formulated.

To assess rework costs in construction projects of Grupo Williams and suggest improvements to reduce these rework costs.

This main objective can be divided into sub-objectives.

- To assess rework costs in construction projects of GW
- To determine the most relevant rework causes
- To suggest improvements to reduce these rework costs

1.3 Research questions

These sub-objectives will be reached by answering the following research questions.

To assess rework costs in construction projects of GW

- How much rework costs occur at projects of GW?
- What or who causes the rework?
- How is the rework classified?
- How did the rework affect time?

To determine the most relevant rework causes

- What causes most of rework?
- What causes the highest rework costs?
- Which causes should be taken on?

To suggest improvements to reduce these rework costs

- How can the causes of rework be reduced or avoided completely?
- How can GW implement the suggested improvements?
- How can GW learn from projects to reduce rework costs in the future?

1.4 Structure of report

In Chapter 2 the research methodology is presented. After these introductions to the research a theoretical background of the studies' scope is presented in Chapter 3. From existing literature a definition for rework is given, and the causes and consequences of rework events are described as well. In the last paragraph of this chapter the scope of this study is presented.

To get an idea of the amount of rework costs within GW, financial records for five realized projects have been studied. The findings are presented in Chapter 4. First the projects are individually discussed after which general conclusions regarding the financial analysis are drawn.

Interviews were held to find the causes of rework. The way these interviews have been set up is described in Chapter 5, the findings in Chapter 6 and the reliability of the data from the interviews is analyzed in Chapter 7.

After the causes had been identified, suggestions for improvements were given. The improvements consisted of suggestions based on theoretical research (Chapter 8) and the development of a rework database and a rework monitoring tool (Chapter 9).

Chapter 10 presents the final conclusions and recommendations.

2 Research methodology

To be able to answer the research questions formulated above several activities have to be carried out. Therefore a research approach, or methodology, has been defined in the preparatory report. The main idea of the proposed methodology has also been followed during my research. The methodology has been schematically depicted in Figure 1, this figure gives a clear and structured overview of the different steps that have been taken during this research. The research methodology will briefly be explained in this section.

2.1 Qualitative analysis of finished projects

Evaluating finished projects can give an idea of the gravity of rework problems within a company's projects. There are several factors that indicate that rework might have happened. In the preparatory phase of this study these indicators have already been identified namely: material, labour, time and total costs. During the research, contract value has also been identified as an indicator. By comparing the estimated amounts of these indicators with the actual realized amounts, an idea of the total failure costs can be presented. This does not result in the actual percentage or costs contributed by rework, it merely shows the gravity of the problem. The evaluations of finished projects are input for the interviews and it is also possible that conclusions can directly be drawn from them. This part of the research will be explicitly described in Chapter 4.

2.2 Rework definition

To be able to conduct this research it is of great importance that the term "rework" has been clearly defined. In existing literature several definitions have been used and therefore different methodologies have been applied and different conclusions were drawn. Defining rework is part of the theoretical framework, Chapter 3.

2.3 Inventorisation of possible rework causes

The evaluation of finished projects is not enough to give a reliable idea of rework occurring within the projects of GW because information has not been collected that detailed. To be able to conduct this research possible causes or indicators of rework must be analyzed. They form a very important part of the model, explained below. Through thorough reviewing of literature many possible causes have been identified. Of course there might be specific causes within a project or new causes might arise in future projects. The inventorisation has not been fully described in this report but the main outcomes can be found in paragraphs 3.4 and 5.1.

2.4 Checklist/model

The checklist/model can be considered as the basis for this research. The definition of rework and the list of possible causes (explained above) are the input for the model. In the model causes have been classified and codified to keep it structured. This model is also the most important input for the interviews. It can be found in Chapter 5.1.

2.5 Interviews

Information about the causes of rework is not available for finished projects. The information has been received from questioning key-employees involved in the projects. Interviews or questionnaires are the most suitable methods when gathering information like this. The personnel that was interviewed was involved in the management or supervision of the projects. The purpose of the

interviews was determining what the causes of the rework, that occurred in specific projects, were. The interviews provide information about the most relevant (sub-) causes.

Every possible cause in the checklist has been questioned for its occurrence in the projects in the interview and the interviewee could rate a cause for its relevance by using a scale. The interview will be explicitly explained in Chapter 5.2 and an example of the interview can be found in Appendix VIII.

Once the interviews had been drawn up, they were conducted. For every project 2 or 3 people have been questioned. The interviews were face-to-face when possible to be able to explain any possible ambiguities and go more into detail when necessary. Afterwards the reliability of the data derived from the interviews has been analyzed and the data has been presented in a structured way to be able to draw conclusions at a glance. There has also been feedback to the checklist.

2.6 Conclusions & recommendations

Once the most relevant causes had been found, suggestions for improvement have been made, see Chapter 8 and 9. The conclusions, recommendations and possible subjects for further research are presented in Chapter 10.

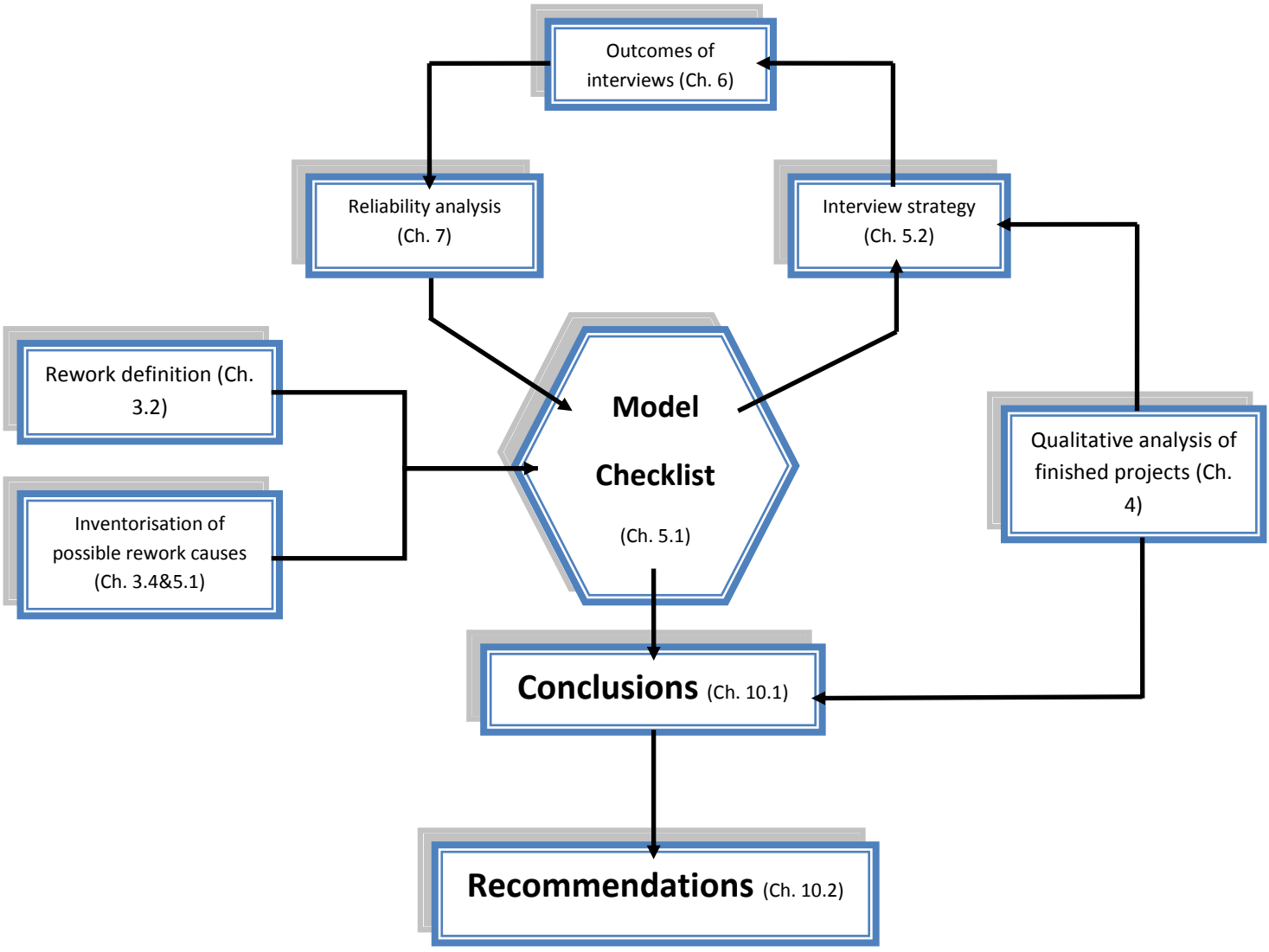

Figure 1 Research methodology schematically

3 Theoretical framework

In this chapter the theoretical background for the research will be described. Failure costs in general will be briefly raised, but since this research focuses on rework costs, there is no need to explain this term very elaborately. Far more important is defining rework as is explained above. Furthermore the consequences of rework will be raised. The results from researches on rework in the past will also be discussed to gain insight in the gravity of the problem. Another very important part of the literature studies was finding possible rework causes, because this is the basis for the model. The theoretical framework described in this chapter delineates the scope of this research study.

3.1 Failure costs

Failure costs are all costs that are made unnecessarily for the final product. Failure costs are caused by an inefficient construction process, by non conformances with the agreed quality claims or because aspects have to be repaired or replaced. (SBR, 2005)

Another, but similar, definition is presented by Love & Edwards (2005) where non-conformance or failure costs are defined as "the cost of inefficiency within the specified process, i.e., over resourcing of excess, materials and equipment rising from unsatisfactory inputs, errors made, rejected outputs, and various other modes of waste" (British Standard BS 6143, 1992).

Failure costs consist of many different costs, a few are; waiting for information, materials or tools, unused equipment or resources, reduced productivity, rework and handling complaints. (AEW Services, 2001) This research will focus on one of these costs, namely rework costs. Therefore there is no need to describe failure costs more elaborately. Love and Irani have concluded that rework is the primary factor of failure costs and time overruns (Love & Irani, 2002b).

3.2 Rework definition

Quite some researches about rework in construction companies have already been executed by several researchers. All of them defined rework or applied someone else's definition at the start of their research. Different definitions of rework are used and therefore different methodologies applied and different conclusions drawn. To be able to answer the research questions a clear definition has to be chosen.

Definitions of rework found in existing literature are:

Construction Industry Development Agency (1995):
"Doing something at least one extra time due to nonconformance to requirements"

Ashford (1992):
"The process by which an item is made to conform to the original requirement by completion or correction"

Love & Li (2000):
"The unnecessary effort of re-doing a process or activity that was incorrectly implemented the first time"

Josephson, Larsson & Li (2002):
"The unnecessary effort of correcting construction errors"

This last definition by Josephson, Larsson & Li is not complete enough as will be made clear later in this chapter. The scope of this research will be wider than just construction errors. Therefore this definition is not applicable. The definition given by Love & Li is based on the definitions of CIDA and Ashford and will therefore be used to define the rework that will be analyzed in this research.

Rework is: "The unnecessary effort of re-doing a process or activity that was incorrectly implemented the first time."

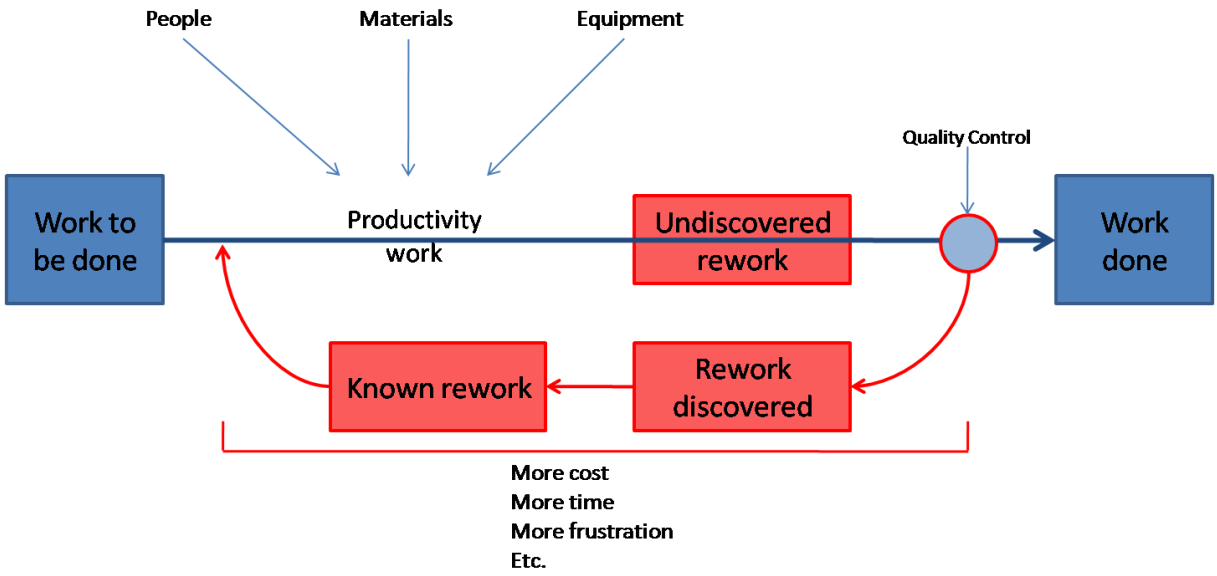

Figure 2 The quality control rework cycle (AEW Services, 2001)

Figure 2 shows the rework cycle in a construction process. At a certain moment during construction, due to for example an error, rework is necessary. But the rework might not be discovered until some form of quality control, after which can be concluded what kind of rework needs to be done and the work start again. This cycle continues until the work has been satisfactorily completed.

Figure 3 shows the rework process from another perspective. There is a certain cause for rework, the rework event as explained above occurs and the rework influences several factors, the indicators. The causes and consequences of rework will be explained elaborately in the next paragraphs.

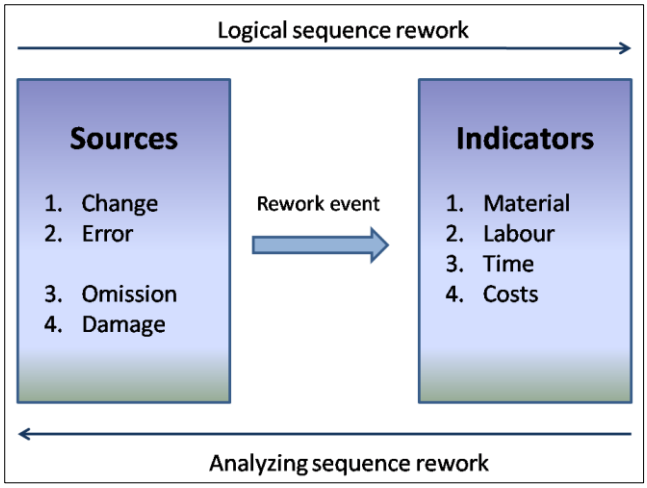

Figure 3 Rework process

3.3 Consequences

Rework can lead to several overruns, and so these overruns indicate that somewhere in the construction process rework might have occurred. This characteristic will be used to locate possible rework in finished projects as has already been explained in the research methodology section. Indicators of rework are mentioned below.

- Redoing things takes time and might therefore lead to time delay. Rework can definitely influence the project planning. Time overrun might be a consequence of rework.
- A second indicator is labour overrun. If work has been done incorrectly this can be seen as non-productive time and rework takes effort and thus extra labour. If more hours (and thus more labour costs) were needed to realize a project than estimated, it might have been because of rework actions.
- Rework often means that parts of a structure have to be scrapped and new material is needed to rebuild it. Extra material used might indicate rework as well.
- The factors mentioned above have one thing in common. Delay, extra labour and extra materials cost money and cost overrun might therefore be the most important indicator for rework.

These are all direct consequences of rework. They are rather easy to identify if administration has been done properly. There are also many indirect consequences of rework (Love P. E., 2002a). Firstly, there are the indirect costs of rework, these are a lot harder, if not impossible to trace. For example, the direct cost of a particular rework consist of the labour costs for the time needed for the rectification and the extra materials that were used. Though the employee might have to travel to the construction site, in the meantime not being able to work elsewhere. So there is the hourly payment for the travelling time and the additional loss of productivity. These are examples of indirect costs. Love found the indirect costs to be as high as six times the direct costs.

There are also several more indirect consequences of rework that are a lot harder to express in terms of money or costs. Additional indirect consequences of rework might be (Love P. E., 2002a):

- End-user dissatisfaction
- Inter-organizational conflicts
- Stress

- Fatigue
- Work inactivity
- De-motivation
- Loss of future work
- Absenteeism
- Poor moral
- Reduced profit
- Damage to professional image

These factors can hardly be assigned a monetary value but can greatly influence a company's present or future well-being.

3.3.1 Gravity of consequences from literature

Many research studies have sought to determine the amount of rework costs within projects. To give an idea of the gravity of rework problems construction companies deal with, Table 1 shows several studies and their findings. This table has been adapted from Love & Edwards (2004). Only numbers that represent rework are shown. Several studies have tried to determine all failure costs as well, they sometimes found numbers as high as 25 to 35 % of the contract values of project costs.

We must take into account that as a result of differences in definitions, scope, data collection methods used, and whether rework is calculated as a proportion of project or contract value, these numbers are not fully comparable. They do give an idea of the scale of rework. For example, the total costs of rework for the Australian construction industry has been estimated at 4.3 billion Australian Dollars, that is just over 3 billion €. (Love & Sohal, 2003)

Author	*Country*	*Costs*	*Comments*
Cusack (1992)	Australia	10%*	* = % of contract value
Burroughs (1993)	Australia	5%*	† = % of project costs
CIDA (1995)	Australia	6.5%*	
Lomas (1996)	Australia	>1%*	
Love et al. (1999)	Australia	2.4% & 3.15%*	
Love (2002)	Australia	6.4%*	
CIDB (1989)	Singapore	5-10%†	
Hammarlund et al. (1990)	Sweden	6%†	
Josephson & Hammarlund (1990-1996)	Sweden	2.3-9.4%*	
Josephson et al. (2002)	Sweden	4.4%*	
Burati et al (1992)	USA	12.4%†	
Abdul-Rahman (1993)	UK	2.5-5%*	

Table 1 Amounts of rework in projects

The numbers presented in Table 1 are mostly from studies in developed countries. Singapore might have been less developed in 1989, but was probably already more developed at that time than Honduras is right now. Therefore we cannot assume that rework costs in Honduras (and other developing countries) are equal to the numbers presented above. Several studies on rework costs in developing countries have also been studied but unfortunately there are not many that give rework costs as a percentage of total project costs or contract value.

Frimpong et al. (2003) concluded that in Ghana 75% of the studied projects had cost and time overruns and Reffat (2004) states that in many developing countries the majority of construction projects have overruns because of lack of management skills. He also claims that without reducing failure costs sustainable development is not possible. Azhar et al. (2008) concludes that cost overrun is a very frequent phenomenon but that this trend is more severe in developing countries where the overruns sometimes exceed 100% of the anticipated cost of the project. Generally we can conclude that cost overruns, and thus most likely rework costs as well, are higher in developing countries than in the western countries where most studies have taken place.

3.4 Causes

There are many possible causes of rework. By studying many existing research studies many possible causes have been identified. In these studies many authors identified similar causes. To prevent the repeated occurrence of similar causes in the model and consequently a very extensive model, more or less similar causes have been taken together. Not all causes will be listed in this chapter, since 45 possible causes have been identified. These 45 causes can be found in the model described in paragraph 5.1. In this chapter the main categories of causes will be mentioned and some examples will be given.

3.4.1 Departments/phases

Rework can occur in pretty much any phase in the construction process or in any department of a company. Burati et al (1992) studied rework in five major areas; design, construction, transport, fabrication and operability. But rework can also occur in the management, administration or accounting department. Most research about rework has studied solely the design and construction phases.

3.4.2 Categories

Most studies on rework have been executed by Peter E.D. Love. In all of his studies he classifies rework into four categories; change, error, omission and damage. This categorization had already been applied by Farrington in 1987. He provides the following definitions:

- Change: a directed action altering the currently established requirements
- Error: any item or activity in a system that is performed incorrectly resulting in a deviation
- Omission: any part of a system including design, construction, and fabrication, that has been left out resulting in a deviation

During a project many changes can occur. Some changes are attended, some unattended and both can have positive and negative influences on the project. Unattended dynamics have not been taken into account at the start of the project and might therefore influence the costs of a project. (Love et al., 2002c)

Love and his fellow researchers state that these changes in circumstances can result in for example downtime and rework, not all the changes he mentioned will lead to rework. Internal uncertainties might be:

- Project-related: location conditions, uncertainties in the contract, uncertain durations for activities, uncertain costs, uncertain technical complexities, and resources availability and limitations

- Organization-related: different project stages require different skills, different contributors and other resources. Project participants vary through the construction process.
- Finance-related: a company's financial capability/policies can change. The changed financial status of any party within the project team can affect, or in the extreme even jeopardize the project's expected outcome.
- Interest-related: although all project participants may appear to desire realization of project goals, the interactive constraints and interests between disciplines often cause conflict. This can hinder co-operation in dealing with changes and affect performance.
- Human-related: the effectiveness of human resources might change

External uncertainties might be:

- Government-related: regulations, taxes. interest rates
- Economy-related: inflation, exchange rates, market competition, availability of labour, materials and finance
- Social: changing social environment, resistances
- Legal: changes in legislation: safety or planning laws
- Technological: materials, techniques, labour, facilities, machines
- Institutional influences: codes of conduct, education regulations
- Physical conditions: infrastructure, transportation, degree of saturation, district development plans
- Acts of God/Force Majeur: weather, natural disasters

As explained above, rework might also occur due to errors, omissions and damage.

Construction errors are the result of incorrect construction methods and procedures and are human-related. Some examples of origins of errors are; certain aspects have been overlooked, lack of or bad communication, poor coordination and integration and lack of skills and training. Regardless of the skill level, experience, or training that individuals possess, errors and omissions may be made at any time. (Love et al., 2009)

Construction omissions are those activities that occur due to omission of some activities and damage may be caused by employees, subcontractors, weather conditions or natural disasters.

3.5 Scope

This research will not deal with all of the possible rework causes and consequences, since some are almost impossible to find or trace and it would be very time consuming to do so. When analyzing the finished projects only the direct consequences of rework will be analyzed since the indirect costs and consequences are hardly traceable. Just finding the direct consequences already was a real challenge. Furthermore will this study only look into rework in two areas, the design and construction phases. In the preparatory report emphasis was solely put on rework during the construction phase but after analyzing some projects, it seemed that there had also been quite a lot of changes to the design which could have caused rework. Also design rework and construction rework turned out be rather overlapping. Therefore the design phase has also been added to the research scope.

From almost every finished study that provided actual numbers for rework categorized by the four types mentioned above, can be concluded that changes and errors are the most contributing causes. For example, in a study where a project for residential apartment blocks in Australia was analyzed, more than 98% of the rework costs was due to changes and errors. (Love & Sohal, 2003) Because omissions and damage costs turned out to be neglectable compared to those originating from changes and errors, in the preparatory report it said that only these two types of causes would be researched. Emphasis was indeed put on these two types of rework during this research, yet also damage has been briefly analyzed. According to Kaming et al. (1997) a major cause of rework in Indonesia (and many other developing countries) was damage to construction due to bad weather or natural disasters. And since Honduras is located in a region susceptible to natural disasters such as hurricanes, earthquakes, floodings and landslides, this possible cause should not be left out in the model.

4 Qualitative analysis of finished projects

The first step of the actual research was the qualitative analysis of finished projects. As already has been stated in the research methodology section, evaluating finished projects can give an idea of the gravity of rework problems within a company's projects. First will be described how the analysis was conducted. After that the results will be presented per project.

4.1 Analysis methodology

In the preparatory phase a plan was made on how to analyze the finished projects. Data of finished projects would be the main source for this part of the research. There are several factors that indicate that rework might have happened; material, labour, time and total costs. By comparing the estimated amounts of these indicators with the actual realized amounts, an idea of the total failure costs could be presented. This would not result in the actual percentage or costs contributed by rework, it would merely show the gravity of the problem. But before an overview of the estimated and realized amounts of the stated indicators could be presented, data had to be collected. Work breakdown structures (WBS) and a projects' planning had been identified as possible sources to analyze data from finished projects. The necessity to always use the WBS and planning drawn up at the same time in a projects' process has also been identified in the preparatory phase of this study. The estimated amounts can vary quite a lot and therefore it is important to always use comparable data. Same goes for the collection of the realized data. There might be several moments in time when the results of a project are assessed.

Unfortunately there was less data available at GW and the data that was available was often not reliable. Gathering the estimated amounts was not the major problem. The tender sent to the client that was used to draw up the initial contract was used to gather information on the estimated amounts. It included total costs, direct costs, indirect costs and contract value. And the estimated amounts of labour costs and material costs could also be calculated from this tender. The contract value has been added as an indicator for rework since a change in contract value often implies changes to the design. Even though the costs are passed on to the client, these changes can still cause rework and the associated (indirect) consequences. For most of the projects there was also a Gantt chart available that showed the estimated amount of days to complete the project.

Analyzing the realized amounts was more of an issue. The balance sheet (departemento de presupuestos) and costs reported by the accounting department (contabilidad) where used. For all projects a balance sheet had been drawn up which included the estimated amounts, the realized amounts, the initial contract value and the actual contract value. Unfortunately these balance sheets were often not complete or did not correspond with the amounts that were received from contabilidad. The results from contabilidad were not complete either, since they did not include costs from subcontractors. In several cases the realized costs were found to be several dozen percentages lower than the estimated amounts, which is highly unlikely, making these numbers unreliable. Also in the balance sheets direct costs were not split up into labour and material, so often numbers from both the balance sheet and contabilidad were used.

For example, in project Banco Lafise the total realized costs according to the balance sheet were L. 4.952.679,92. The costs accounted for by contabilidad on the other hand were L. 7.882.971,08: a difference of almost 60%.

The numbers that were likely to be the most realistic were used to analyze the projects. Even though they were often not complete, some indicators for rework were still identified. Another disappointment was the lack of documentation of the realized planning. For most of the projects the actual amount of days of construction had not been documented and could not be provided, making it impossible to provide an answer to the question how rework affected time in the projects. Also intermediate evaluations were not useful since they only included amounts that had been paid by the client.

4.2 Projects

In total five projects have been analyzed. Most of GW's projects are design & construct but at times they also take up projects for which the design has been made elsewhere. In Table 2 the projects are briefly presented. Each project will first be analyzed individually and at the end a short comparison will be made. The complete financial analyses can be found in Appendix II - VI.

Project	Type of project	End contract value
Banco Lafise	Construct	L. 11.461.453,73
Cervezeria Hondureña	Design & Construct	L. 9.242.395,75
Aimar	Design & Construct	L. 14.276.532,02
Cigrah	Design & Construct	L. 10.952.878,26
Panaderia Jerusalen	Design & Construct	L. 7.265.446,26

Table 2 Overview of analyzed projects

4.2.1 Proyecto Banco Lafise

Most of the projects of GW are design-construct contracts, this project however has been designed elsewhere. The project includes the renovation of the office of Banco Lafise in San Pedro Sula, a large bank in Central America. The design was made by a company in Nicaragua.

As already mentioned in the example above, the financial evaluation of this project is not very solid. The balance sheet (presupuestos) does not correspond with the numbers from the accounting department (contabilidad). The total realized costs according to the balance sheet were L. 4.952.679,92. The costs accounted for by the accounting department were L. 7.882.971,08: a difference of almost 60%. The numbers from the accounting department are more realistic and more detailed and have therefore been used. These numbers are not complete either though. Payments to subcontractors were not included in the overview that was provided. Taking into account that a part of these contracts is material cost and another part labour cost, the realized amounts for these indicators are higher than presented. Especially the labour cost comparison is unreliable, a 57% reduction is very unlikely. Since a lot of costs are missing only conclusions that do give some kind of useful information will be presented. The analysis of the indicators lead to the following findings:

- Material costs were 27% higher than estimated (this percentage is probably even higher since subcontracts are missing)
- The end contract value was 14% higher than the original contract
- Seven change orders have been made

In Table 3 a summary of the numbers for Banco Lafise is presented. The red marked numbers indicate that rework might have happened.

Rework indicator	Estimated amount	Actual amount	% difference
Material	L. 4.341.685,59	L. 5.494.121,88	+27%
Labour	L. 4.028.840,12	L. 1.739.462,41	- 57%
Time	107 days	N.A.	N.A.
Total costs	L. 9.205.185,48	L. 7.882.971,08	- 14%
Contract value	L. 10.068.315,57	L. 11.461.453,73	+14%

Table 3 Financial analysis of proyecto Banco Lafise

4.2.2 *Proyecto Cervezeria Hondureña*

This is a very recent project of GW. Both the design and construction of the new office/warehouse of la Cerveceria Hondureña have been in GW's hands. La Cerveceria Hondureña is the producer of many drinks, sodas and beers in Honduras. The construction was mostly metal-based.

Again the information from the balance sheet (presupuestos) and the accounting department (contabilidad) did not correspond. Only this time the numbers from the balance sheet were higher but since they approached the estimated numbers a lot more, these were used for the comparison. The costs listed on the turnout received from the accounting department were an average of 37% lower than estimated, but again subcontracts were missing. But when a printout of the subcontracts was received, the total costs were still lower than the costs on the balance sheet made up by the project manager.

The balance sheet did include subcontracts, unfortunately it was not clear which part of the costs of the subcontract was attributable to materials and which part to labour. The same ratio between material and labour cost for GW directly has been assumed. A realized time schedule was again not available. The most important conclusion is:

- Estimated labour costs were exceeded by 13%

In Table 4 a summary of the numbers for Cerveceria Hondureña is presented. The red marked numbers indicate that rework might have happened.

Rework indicator	Estimated amount	Actual amount	% difference
Material	L. 4.488.389,39	L. 3.817.078,80	- 15%
Labour	L. 2.761.802,09	L. 3.120.917,72	+13%
Time	120 days	N.A.	N.A.
Total costs	L. 8.429.626,85	L. 7.539.116,01	- 11%
Contract value	L. 9.242.395,75	L. 9.242.395,75	0%

Table 4 Financial analysis of proyecto Cerveceria Hondureña

4.2.3 *Proyecto Aimar*

This project included the design and construction of several offices and warehouses near the airport of San Pedro Sula.

The way this project has been evaluated by GW is a slightly better than the projects described above. There finally is uniformity between the numbers used in the balance sheet (presupuestos) and the numbers of the accounting department (contabilidad). It is very clear that the department of presupuesstos has used the numbers of contabilidad because the same cost items are used. The

numbers are not exactly the same but differences are negligible. This is due to the fact that the accounting department processed some additional costs after the balance sheet had been drawn up.

However in the balance sheet additional costs have been added under the name "notas de creditos", credits or expenses. It does not become clear what these expenses are. They might be subcontracts and thus include both materials and labour but since this is too uncertain, they have been added under total costs. Again subcontracts were not included in the numbers supplied by the accounting department. Because of this the realized material and labour costs are once more unreliable and since they are a lot lower than estimated they do not provide any information about possible rework.

For this project there was actually a work planning available that showed how work had been carried out. This schedule and the indirect costs provided indications of rework occurring in proyecto Aimar. The change orders were rather slim but as well indicate that rework might have occurred:

- Indirect costs were 159% higher than estimated
- The estimated time schedule was overrun by 37 days, an overrun of 26%
- Two change orders were made although they were rather slim

In Table 5 a summary of the numbers for proyecto Aimar is presented. The red marked numbers indicate that rework might have happened.

Rework indicator	Estimated amount	Actual amount	% difference
Material	L. 7.140.220,77	L. 5.205.622,50	- 27%
Labour	L. 4.022.856,35	L. 2.684.297,44	-33%
Time	145 days	182 days	+26%
Total costs	L. 11.621.008,14	L. 10.526.628,84	-9%
Contract value	L. 13.997.163,46	L. 14.276.532,02	+2%

Table 5 Financial analysis of proyecto Aimar

4.2.4 Proyecto Cigrah

The information received from this project leaves much to be desired. First of all an estimated chronogram of the work was not even available, let alone a realized chronogram. Time as an indicator of rework could thus not be analyzed. Secondly the estimated costs in the tender only included direct costs (labour and materials), indirect costs were not included. Then there is the way the balance sheet (presupuestos) has been drawn up. The realized costs once more do not correspond with the numbers from the accounting department (contabilidad), although according to the project manager the numbers were received from the accounting department. But the difference is considerable, the numbers used in the balance sheet are 1,4 million Lempiras lower. This time the estimated costs assumed in the balance sheet do not even correspond with the estimated amounts in the tender.

According to the balance sheet the profit from this project was higher than estimated. But according to the tender used to draw up the initial contract and the numbers provided by the accounting department the profit is considerably lower than the estimated profit. This of course is not acceptable and is extremely worrying since it can lead to major losses without anyone noticing. We

do have to take into account that the estimated costs do not include indirect costs but since the realized indirect costs are very small, less than 2% of the total costs, this can be neglected.

The numbers from the accounting department have been used to compare the estimated and realized amount. A very high cost overrun can already be noticed but since subcontracts are not included they might even be higher, and looking at the very low realized material costs this is quite likely. Especially the overrun for labour costs is extreme, an overrun of 232%.

The following conclusions regarding to rework can be drawn:

- Labour costs had an extremely high overrun of 232%
- Total costs had a 54% overrun
- Three change orders resulted in a 40% higher contract value
- Estimated profit was L. 999.846,47
  Realized profit was L. 478.084,23 -
  Profit was 52,2% lower: L. 521.762,24

In Table 6 a summary of the numbers for proyecto Cigrah is presented. The red marked numbers indicate that rework might have happened.

Rework indicator	Estimated amount	Actual amount	% difference
Material	L. 4.426.865,64	L. 2.359.979,94	- 47%
Labour	L. 2.383.696,88	L. 7.911.606,64	+232%
Time	N.A.	N.A.	N.A.
Total costs	L. 6.810.562,52	L. 10.474.794,03	+54%
Contract value	L. 7.810.408,99	L. 10.952.878,26	+40%

Table 6 Financial analysis of proyecto Cigrah

4.2.5 *Proyecto Panaderia Jerusalen*

Once more the balance sheet (presupuestos) and accounting department (contabilidad) present different costs. The costs presented by the accounting department are again not very useful since subcontracts are missing. The subcontracts are included in the balance sheet and therefore the results presented there are also more likely to be realistic. Unfortunately the balance sheet does not present the costs for materials or labour separately. It seems to be missing indirect costs as well. The balance sheet has also been drawn up totally different than the ones from the previous projects. Consistency in the way of evaluating projects is hard to find. A comparison of the estimated and actual amount of construction days could not be made since both schedules were missing.

To be able to present more than just the compared total costs, the material, labour and indirect costs have been calculated based on assumptions. Although these numbers are unreliable they do give an idea about the project. The ratio of material and labour costs derived from the numbers of the accounting department, has been applied to the total costs in the balance sheet to gain insight in the realized material and labour costs. Since indirect costs were not included yet, these have been added as well. These assumptions make the numbers unreliable but they are still more likely than the costs presented by the accounting department or balance sheet.

Whether using the balance sheet or the combined data every single indicator encounters overruns in this project. The only difference is the gravity. The following conclusions can be drawn:

- Material costs overrun the estimated amounts by 59%
- Labour costs are 17% higher than estimated
- Total costs are 45% higher than estimated
- Due to change orders the contract value has gone up 20%
- Even though the balance sheet shows a minor profit, the project has most likely made losses. The realized profit (or loss in this case) is estimated at L. - 453.032,28. This is 164% lower than the estimated profits.

Rework indicator	Estimated amount	Actual amount	% difference
Material	L. 2.959.538,14	L. 4.712.609,47	+59%
Labour	L. 2.011.810,49	L. 2.363.380,73	+17%
Time	N.A.	N.A.	N.A.
Total costs	L. 5.337.857,76	L. 7.718.478,54	+45%
Contract value	L. 6.048.575,33	L. 7.265.446,26	+20%

Table 7 Financial analysis of proyecto Panaderia Jerusalen

4.3 Conclusions regarding possible rework

Even though the evaluation of the projects could not be carried out as planned and numbers are less reliable than anticipated, indications of rework have been identified. In all of the evaluated projects at least one of the indicators had experienced an overrun. These overruns are failure costs and as explained in the theoretical framework (Chapter 3) a part of these costs is caused by rework processes. Only total overrun percentages could be presented since rework has not been specifically evaluated during any of these projects or any of GW's projects at all. The following conclusions regarding rework could be drawn:

- Average total cost overrun (average failure costs) was 13%. But at least two of the five projects had a total cost overrun, resulting in less profit and even losses. The cost overruns were far from neglectable, respectively 45% and 54% higher costs than estimated have been realized.
- Four out of five projects had to process change orders. These change orders resulted in increased revised contract values of up to 140% the initial values. The costs involved with these changes are passed on to the customers. So GW does not take on the direct costs of this rework but the indirect consequences mentioned in paragraph 3.3 are still applicable. Therefore change orders should also be avoided even though the direct costs are for the client.
- Material and labour cost overruns are also frequent, respectively two out of five and three out of five projects incurred these overruns. Material overruns were as high as 59% of the estimated costs and labour costs were even found to be 232% higher. These overruns are most likely even higher and more frequent since numbers were yet missing.

- If the change orders are completely seen as rework, they make up for a major part of the cost overruns. This assumption is questionable because according to the definition presented in paragraph **Fout! Verwijzingsbron niet gevonden.** rework is the unnecessary effort of re-doing a process or activity that was incorrectly implemented the first time. And not every part of a change order fits that definition. But it can be seen as a consequence of re-doing a process that was incorrectly implemented the first time. If the design had been correct the first time, no change order would have been required but due to changing the design, many extra activities might be required. These are not rework themselves but are a consequence of rework.

  For the two projects that had total cost overruns the change of the contract value (the change orders) has been compared to the total cost overrun. These calculations are based on several assumptions and are therefore not very reliable but they give an indication about what part of failure costs are due to rework. For La Cigrah the value of the change orders is 86% of the value of cost overruns. For La Panaderia this percentage is lower, 51%. These percentages only include change orders and there are more rework causes which will be described further on in this report and therefore actual rework percentages will be even higher. But these percentages do give an idea about which part of failure costs is due to rework. As already described above the change order costs are mostly passed on to the client but should be avoided nevertheless.

4.4 Conclusions regarding financial project evaluation & accounting

After analyzing five realized projects some conclusions can already be drawn regarding some general processes within GW. These conclusions do not relate to rework but to general financial project evaluation aspects.

Summarizing the conclusions that have been drawn, detailed explanations can be found below:

- ***There is hardly any uniformity between the balance sheet drawn up by the deparment of presupuestos and the numbers from the accounting department (contabilidad). If there is uniformity it is almost impossible to trace due to different layouts, structures and codifications.***
- ***The accounting department (contabilidad) is not able to provide an overview of the total financial situation of a project. There should be an overview that gives an idea about the projects' financial situation at a glance.***
- ***The way projects are being evaluated, specifically the way the balance sheet is drawn up, is not standardized.***

4.4.1 Uniformity balance sheets and accounting & end result overview

In four projects the balance sheet made by presupuestos and the overview of the accounting department (contabilidad) did not correspond. There was no clear unequivocality in the differences because at times the costs in the balance sheet were a lot higher than those registered by the accounting department, but for other projects the balance sheet numbers were a lot lower than the ones from accounting. It does not seem to be a systematic difference. To be able to evaluate a project properly it is of great importance that every department uses the same financial numbers. It was clear that at times costs were missing in the balance sheets that had been drawn up by the

project managers. However it is not clear if the same goes for the accounting department, since the turnout received for the projects did not include subcontracts. Therefore it might very well be the case that the accounting department does have all costs registered, but because a complete overview of a project could not be provided it is very hard to compare some numbers.

The lack of ability to produce a complete and structured overview of a projects expenses is probably one of the reasons there are so many differences between the numbers used within the company. The accounting department should be the department with the overview of all the costs made within a project. If the department of presupuestos uses the same structure and codification as the accounting department and of course the numbers provided by the accounting department, the balance sheets become much more reliable. Because at this moment they are far from reliable.

In one project, proyecto Aimar, it is very clear that to draw up the balance sheet the numbers from the accounting department were used. This makes comparing the numbers a lot easier and makes the balance sheet more reliable since costs can be traced.

Inadequate accountancy can be very dangerous. For example in the case of Panaderia Jerusalen it is very likely that the project made losses even though the balance sheet shows a minor profit. The company might endure losses without even knowing it. In less profitable times errors like these show up at the end of the year and if it happens on a larger scale it might even mean the bankruptcy of a company.

When this was presented the differences between the numbers could not be explained but it was confirmed that the differences in codifications have been a problem for several years now. Tracing numbers has always been difficult and it was agreed that it really is something that needs to be evaluated properly.

4.4.2 Standardization balance sheets (and tenders)

The way balance sheets have been drawn up by the department of presupuestos is not standardized. It is often not clear where the numbers have been derived from and different sources of the numbers presented seem to have been used. Also the balance sheets do not provide the same kind of numbers and furthermore is the layout not alike. To be able to evaluate projects properly a standardized way of drawing up the balance sheet should be adopted. It makes it easier to draw up the balance sheets, it is easier to trace costs and a summary of the projects results can be provided at a glance.

The set up for the balance sheet of for example proyecto Banco Lafise is actually quite good. It includes the initial contract value, all the change orders, the end contract value, the estimated costs and results, realized costs and results and the received payments. The problem within this balance sheet lies within the non-existing uniformity problem described above. As described above, the balance sheet of proyecto Aimar does contain uniformity. So combining the ways these balance sheets have been made, would already be an improvement.

The tenders (also made by the department of presupuestos) are already standardized. At least for four projects the same tender format had been used. These are clear and structured.

5 Set-up quantitative analysis of finished projects

We now know approximately how many rework costs occur at projects of GW, so next it is important to find the causes of rework events. This will be done through quantitative analysis of the same project. In this chapter the model and interviews that were part of these analyses are presented.

5.1 Model/Checklist

As already explained in the research methodology section, the model or checklist can be considered the basis for this research. By thoroughly reviewing existing literature many possible causes for rework have been identified. In Chapter 3.5 is described that not all the possible causes have been examined. The causes have been classified and codified to keep it structured and clear. The first subdivision is the phase in which the rework occurs, namely design and construction. The other subdivision is the type of rework; error, change and a few that do not fit into these two categories, but are important to analyze. Some causes are difficult to classify. A change in the design initiated by the client for example, might also cause rework at the construction site if construction has already reached that certain stage of construction. To avoid causes appearing twice, they have only been included in the design section.

To make the checklist even more structured the causes have been grouped by similarity and responsibility. For example all construction errors caused by executing personnel has been grouped. For the rework causes related to the design stage this is less applicable since they always apply to (at least) the designer.

To make processing of the interviews easier and structured, the causes have been codified. The codification is explained in Table 8. The model itself can be seen on the next page (Table 9). In Appendix I the same model is presented, here the literature where the causes have been derived from has been added.

Code	Explanation
DE	Design error
DC	Design change
DO	Design others
CE-E	Construction error by executor
CE-S	Construction error by supplier
CE-M	Construction error by management
CC-C	Construction change by client
CC-E	Construction change by executor
CO-E	Construction others by executor
CO-D	Construction others namely damage

Table 8 Model codification explained

	Phase	Type	Cause	Code
Rework	Design	Error	Lack of co-ordination	DE1
			Unsuitable design	DE2
			Design is hard to construct	DE3
			Faulty design	DE4
			Incomplete drawings	DE5
			Erroneous drawings	DE6
			Not enough time to design (given by contractor)	DE7
		Change	A design change is initiated by the contractor	DC8
			A design change is initiated by the end user/occupier	DC9
			A design change is initiated by a supplier	DC10
			A design change is initiated by Grupo Williams	DC11
			A design change is initiated due to financial changes	DC12
			A design change is initiated due to economic changes	DC13
			A design change is initiated due to social changes	DC14
			A design change is initiated due to legal changes	DC15
		Other	Communication problems	DO16
			Interpretation problems	DO17
	Construction	Error	Omission errors by construction personnel	CE-E18
			Mistakes in executing rules	CE-E19
			Noncompliance of rule	CE-E20
			Slips/lapses of attention	CE-E21
			Erroneous workmanship	CE-E22
			Faulty material handling	CE-E23
			Faulty machine handling	CE-E24
			Insufficient cleaning	CE-E25
			Damage caused by GW or a subcontractor	CE-E26
			Inexperienced personnel	CE-E27
			Late deliveries of materials	CE-S28
			Faulty manufacturing of materials	CE-S29
			Material hard to work with	CE-S30
			Delivery with wrong type of materials	CE-S31
			Mistakes in planning	CE-M32
			Faulty work preparation	CE-M33
			Faults in materials administration	CE-M34
			Wrong setting up	CE-M35
		Change	Changes in clients' wishes	CC-C36
			Bad choice of material by client	CC-C37
			Extra orders by client	CC-C38
			Wrong information given by client	CC-C39
			A change in construction methods in order to improve constructability	CC-E40
			A change in construction methods due to site conditions	CC-E41
		Other	Machine not working satisfactorily	CO-E42
			Machine breakdown or defects	CO-E43
			Damage due to weather conditions	CO-D44
			Damage due to natural disasters	CO-D45

Table 9 Model

5.2 Interview strategy

The data necessary to determine rework has occurred is not available for finished projects because rework events have never been reported. The information has been received from questioning employees involved in the projects. Interviews or questionnaires are the most suitable methods when gathering information like this. The personnel that was interviewed was involved in the management or design of the projects. The purpose of the interviews was determining what the causes of the rework, that occurred in specific projects, were. The interviews provide information about the most relevant (sub-) causes.

Every possible cause in the checklist has been questioned for its occurrence in the projects in the interview and the interviewee could rate a cause for its relevance by using a scale with possible answers ranging from strongly agree to strongly disagree. In Appendix VIII an example of the surveys that were conducted during this research to analyze the causes of rework in some realized projects of GW can be found. Only a part of the interview has been adopted in this report since the complete interviews are very large and since an overview of the assertions is presented in Appendix VII this is unnecessary.

Once the interview-questions had been determined, the interviews were conducted. For every project the goal was to question three people, two project managers and the head designer. The interviews were face-to-face to be able to explain any possible ambiguities and go more into detail when necessary. Unfortunately the head designer for the analyzed projects had holidays while the interviews were conducted. But even though she had holidays she offered to fill in the survey herself. So these interviews were not held in person but the responses still provided useful information. Afterwards data derived from the interviews has been analyzed and presented in a structured way to be able to draw conclusions at a glance. There has also been feedback to the model.

The purpose of the interviews was determining what the causes of the rework, that occurred in specific projects, were.

Most of the theoretical information presented below has been received from Fink (2006), Edwards et al. (1997) and Steehouder (2006).

5.2.1 Checklist as basis

The checklist or model presented in Table 9 was the basis for the interviews. Every single cause was tested for occurrence during a project by presenting a statement involving that cause. An overview of all the assertions presented during the interviews can be found in Appendix VII. The main advantage of the checklist is that it reminds people of possible causes that they might forget when they would have been presented open questions about the causes of rework that occurred during a project.

5.2.2 In-Person interviews

The interviews were conducted in person. The main advantages of doing so were the possibilities to explain questions or words that were unclear to the interviewee or to probe answers with the respondents and thus getting more detailed information. Since many employees of GW were not familiar with rework and the language sometimes was a problem this was very important. Because of the in-person conduction the interviews did take more time.

Self-administered questionnaires would have been useful when there had been a few simple questions that did not need further explanation or when further illustration or answering would not have provided any more possible useful information.

5.2.3 Standardized vs. non-standardized interviews

With standardized interviews, each interviewee is asked exactly the same questions. They are suitable for collecting factual information and are mostly applied when trying to reveal standard patterns.

Non-standardized interviews are less structured and questions vary per interview. They are suitable for detailed examination of certain topics, when dealing with sensitive or emotive aspects or when projects or businesses have very different characteristics.

For this research a semi-standardized interview was used. An aspect that can be seen as non-standardized was the possibility to go into detail for each question. But per project the same questions were asked to each person and a standard list of statements was used. Semi-standardized interviews give the interviewer the flexibility to adapt to the specific circumstances while ensuring comparable data is gathered.

5.2.4 Open vs. closed questions

Open questions give the interviewee the possibility to answer the questions in their own way. Closed questions on the other hand do not give this possibility. The interviewee has to chose from several given answers. This interview mostly consisted of closed questions since they produce results that are more easy to process. The reliability is also higher because all the answers are classified similarly, everyone has to choose from the same options. Because the interviewee might have useful additional information it was possible to go into a specific aspect more thoroughly. By doing this the disadvantages of closed questions have been gotten around.

5.2.5 Use of scaling

Besides finding what causes were relevant for the studied projects, it was also important to find the gravity of the causes. Therefore solely using a checklist was not sufficient. Using an answering scale the interviewee is given the possibility to express the gravity of that specific rework origin within the project. There are many different possible scales. Some things to consider when choosing the scale:

- Make sure the scale is always the same
- Make sure the scale always has the same meaning
- Make sure there are as many positive as negative ratings
- Make sure answer possibilities are not too close to each other

In this survey the answering options were; strongly agree, agree, undecided, disagree, strongly disagree and do not know. This is one of the most frequently used Likert scales.

5.2.6 Things to avoid

To gather reliable information and to make sure the interview goes smoothly there are several things that had to be avoided in the questions, namely:

- Jargon
- Unclear questions

- Questions that can be interpreted in several ways
- Negative questions
- Abbreviations
- Abstract questions
- Biased questions or words
- Multiple questions in one phrase

5.2.7 Risks regarding interviews

There are several things that had to be taken into account before drawing up and conducting the interviews, namely:

- People might be unwilling to answer particular questions (for example when they are responsible for errors)
- People might be unable to answer particular questions (for example because of their function within the company)
- People might have forgotten certain aspects since projects have been completed in the past
- Be careful when asking for personal information
- There will be a language barrier that might cause problems. To reduce the language barrier the interview has also been written and explained in Spanish.

6 Outcomes of quantitative analysis

Per project a short summary of the outcomes of the interviews will be given and the most severe problems that were found will be described. An overview of the confirmed indicators for rework per project can be found in Appendix X. After discussing the findings per project, a summary of all the projects together will be given and there will be feedback to the model as presented in Table 9.

6.1 Proyecto Banco Lafise

The financial analysis of this project showed that the cost overrun of materials and the revised contract value were most likely the most important indications for rework. This was also confirmed by the surveys. In total 23 out of 45 rework indications were confirmed. Many of the indicators regarding the design phase were confirmed, very important here is that the design for Banco Lafise was not made by GW but by a company in Nicaragua as has already been explained before.

There were many problems regarding the design, the most important ones are:

- Faulty and incomplete design
- Incomplete and incorrect drawings
- Communication and coordination were not good
- Many design changes were made, mostly by the client but also by the contractor, GW and because of financial and economic changes

The most important problems during construction were:

- The design changes had to be processed
- Construction personnel made errors, mistakes etc. which caused damage
- A subcontractor caused a lot of problems and had to be fired
- A change in construction methods was made to improve constructability
- Research into the underground had not been sufficient
- Machinery breakdown
- Late material deliveries (fault of GW)
- Material prices had gone up

6.2 Proyecto Cerveceria Hondureña

The financial analysis of this project did not result in major indications of rework, only labour costs were found to be higher than expected. In total 16 assertions were confirmed to indicate rework and most of them apply to the construction phase. The design phase went relatively smooth.

The most relevant problems were:

- Lack of coordination during the design phase
- Design changes were initiated by the client (the client was very nervous and changed his mind several times)
- Slips, lapses of attention, errors, and lack of workmanship caused problems. Many of these originated from mistakes by the engineering personnel.
- Engineering and construction personnel did not have much experience
- Lack of space made construction difficult and resulted in a change of construction methods
- Problems with machinery

6.3 Proyecto Aimar

The financial analysis of this project resulted in one major indication for rework, namely a large time overrun. Also there had been two minor change orders. During the interviews 16 assertions confirmed possible rework and questioning the interviewees gave good insight into the problems that were faced during this project (see below).

- Design changes and extra orders were initiated, most of them by the client
- There were major financial problems that lead to design changes and time overruns, because the client did not have sufficient money to pay GW
- Errors, omissions, slips and lapses of attention of construction personnel happened for example in the construction of the foundation
- Materials were delivered too late (fault of GW)
- Changes in construction methods had to made mostly because of problems with site conditions (the underground and groundwater levels)
- Machinery breakdown happened

6.4 Proyecto La Cigrah

In paragraph 4.2.4 it has been concluded that there has been a large cost overrun for this project. The total costs were 54% higher than estimated and labour costs were an exorbitant 232% higher. There had also been a substantial increase in contract value. The interviews gave insight in some of the projects' problems and the origins of the costs but why labour costs were that much higher than estimated could not be explained. A total of 19 indicators has been confirmed for La Cigrah. However there are many discrepancies in the answers of the interviewees since 13 indicators have only been checked by one person. Many of the design related indicators for example have only been checked by the designer, this could for example indicate lack of communication.

The overruns in this project were mainly caused by the following problems. Design related problems:

- Design changes were initiated by the client, contractor and supplier but the client was the most important factor
- Design changes were initiated because of financial and economic changes
- Most of the extra costs were due to extra orders
- The design was hard to construct
- The design was not correct and the drawings were not correct and complete either
- The designer was not given sufficient time
- The communication during the design phase was not sufficient

Construction related problems:

- Damage to walls was caused because of problems with materials and the underground
- Materials were not delivered on time (fault of GW)
- Changes to construction methods were made, also because of problems with the underground
- A lot of problems with machinery; machinery defects and shortage of machinery
- The project was located far from San Pedro Sula which made some aspects more difficult

6.5 Proyecto Panaderia Jerusalen

For this project large cost overruns have been identified from the financial analysis. Material costs were 59% higher, labour costs were 17% higher and the total costs 45% higher. Also the contract value had gone up 20%. But even though there have been large overruns, relatively few indicators for rework have been confirmed in the interviews, namely 15. By further questioning the interviewees the main problems have been identified and most of the cost overruns were due to problems that did not include rework (and therefore can be seen as other failure costs). Most of the problems were caused by the client.

- Many design changes were initiated by several parties and due to several changes (but mostly by the end user/client)
- Extra orders by the client
- Communication and coordination problems
- Financial problems with loan of client: the client did not have enough money because he had to sell old property first
- Construction started a year later than planned (due to financial problems)
- Due to the delay of construction start materials had gone bad and had to be bought again
- Late deliveries of materials (fault of GW)
- Machine breakdowns

6.6 Summary

After discussing the confirmed indicators and other problems that occurred during the projects an overview of the confirmed indicators for all projects can be given. In Appendix XI an overview of the outcomes of the interviews is presented in Table 26. A summary of this table is given below, and the same information has been presented in a bar chart in the appendix, see Figure 5. The most important conclusions that can be drawn from these tables and figures are that five indicators have been confirmed in all projects (11%), that seven indicators have been confirmed in four projects (15%) and four indicators in three projects (9%) . Thus 35% of the indicators has been confirmed in more than two projects (and thus in more than half of the analyzed projects). Table 10 gives a summary of the frequencies indicators have been confirmed and also functions as a legenda for Table 11. This information has also been processed in the initial model, this presents a clear overview of the most frequently occurring rework-indicators, see Table 11.

# of projects	Frequency (indicators)	Colour in revised model
0	13	
1	8	
2	8	
3	4	
4	7	
5	5	

For example, thirteen indicators have not been confirmed for a single project and eight indicators have been confirmed for one project.

Table 10 Summary confirmed indicators overall and legenda revised model

	Phase	Type	Cause	Code	Freq.
Rework	Design	Error	Lack of co-ordination	DE1	4
			Unsuitable design	DE2	2
			Design is hard to construct	DE3	1
			Faulty design	DE4	2
			Incomplete drawings	DE5	2
			Erroneous drawings	DE6	2
			Not enough time to design (given by contractor)	DE7	1
		Change	A design change is initiated by the contractor	DC8	5
			A design change is initiated by the end user/occupier	DC9	5
			A design change is initiated by a supplier	DC10	2
			A design change is initiated by Grupo Williams	DC11	2
			A design change is initiated due to financial changes	DC12	4
			A design change is initiated due to economic changes	DC13	4
			A design change is initiated due to social changes	DC14	1
			A design change is initiated due to legal changes	DC15	1
		Other	Communication problems	DO16	1
			Interpretation problems	DO17	1
	Construction	Error	Omission errors by construction personnel	CE-E18	2
			Mistakes in executing rules	CE-E19	3
			Noncompliance of rule	CE-E20	3
			Slips/lapses of attention	CE-E21	3
			Erroneous workmanship	CE-E22	1
			Faulty material handling	CE-E23	0
			Faulty machine handling	CE-E24	0
			Insufficient cleaning	CE-E25	0
			Damage caused by GW or a subcontractor	CE-E26	3
			Inexperienced personnel	CE-E27	1
			Late deliveries of materials	CE-S28	4
			Faulty manufacturing of materials	CE-S29	0
			Material hard to work with	CE-S30	0
			Delivery with wrong type of materials	CE-S31	0
			Mistakes in planning	CE-M32	0
			Faulty work preparation	CE-M33	0
			Faults in materials administration	CE-M34	0
			Wrong setting up	CE-M35	0
		Change	Changes in clients' wishes	CC-C36	5
			Bad choice of material/method by client	CC-C37	0
			Extra orders by client	CC-C38	5
			Wrong information given by client	CC-C39	2
			A change in construction methods in order to improve constructability	CC-E40	4
			A change in construction methods due to site conditions	CC-E41	4
		Other	Machine not working satisfactorily	CO-E42	4
			Machine breakdown or defects	CO-E43	5
			Damage due to weather conditions	CO-D44	0
			Damage due to natural disasters	CO-D45	0

Table 11 Revised model including frequency of occurrence of indicators after interviews

The most frequently occurring indicators apparently are rather permanent in GW's projects and because they happen so frequently it is very likely that they happen due to systematic errors or inefficiencies. The most frequently occurring indicators are:

Design-phase

- A design change is initiated by the contractor
- A design change is initiated by the end user/occupier
- A design change is initiated due to financial changes
- A design change is initiated due to economic changes
- Lack of co-ordination

Construction-phase

- Changes in clients' wishes
- Extra orders by client
- Machine breakdown or defects
- Machine not working satisfactorily
- Late deliveries of materials
- A change in construction methods in order to improve constructability
- A change in construction methods due to site conditions
- Mistakes in executing rules
- Noncompliance of rule
- Slips/lapses of attention
- Damage caused by GW or a subcontractor

In Figure 4 these most frequent indicators have been presented per category and it can be seen that 50% is change-related, 37% is error-related and 13% falls into another category. From the financial analysis it can also be concluded that change-related rework is the most severe cause of failure costs.

In paragraph 4.3 it was concluded tot a very large percentage of the total cost overruns was due to change orders and that this could be seen as an indication for the amount of rework. The interviews confirm these findings. According to the interviewees the biggest cost overrun cause was change orders and the data presented in Figure 4 substantiates these allegations.

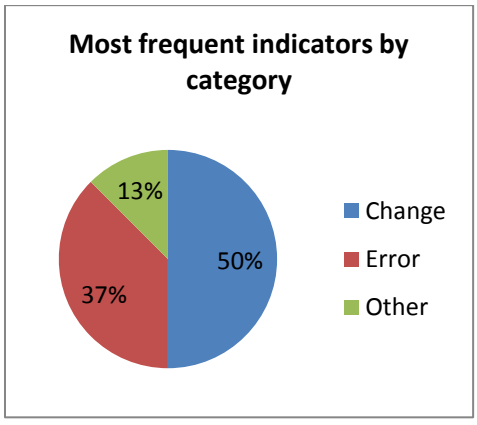

Figure 4 Indicators by category

7 Reliability quantitative analysis

Now the surveys have been conducted, the outcomes should be analyzed for reliability. Reliability can be defined as a measurement of reproducibility of the findings of the survey (statistics.com, 2010). Every survey that involves human cooperation contains errors. There are two types of errors; random errors and measurement or systematic errors. Random errors are always present and are caused by unpredictable fluctuations that vary from measurement to measurement. Random errors can be made neglectable by repeating the measurement several times. Systematic errors are caused by any factors that systematically affect measurement of the variable across the sample. They are predictable and cannot be made neglectable by repeating the measurement since it influences the measurement in the same way at all times. (Trochim, 2006) Because of these errors it is necessary to test the reliability of the surveys outcomes.

There are several methods to test a surveys' reliability (Litwin, 1995):

- Test-retest reliability tests the reliability by redoing the whole survey at another time among exactly the same population
- Alternate form reliability tests the reliability by presenting differently worded items that are similar but not identical and comparing the answers for correlation to determine the reliability.
- Internal consistency reliability measures whether several items that propose to measure the same general construct produce similar scores.
- Inter-observer reliability measures the stability of answers of different respondents for the same questions.
- Intra-observer reliability measures the stability of answers of the same respondent at different times.

In this survey test-retest and intra-observer reliability have not been measured since time did not allow to do so. Internal consistency has been measured by applying alternate form reliability. Inter-observer reliability has been measured by analyzing discrepancies between the answers of different interviewees and by comparing the ratios of confirmed indicators per function.

Only the outcomes of the tests will be presented in this chapter, the tests themselves are presented in Appendix XII.

7.1 Ratios of confirmed indicators

Figure 6 to Figure 10 in Appendix XII show the analysis of the ratios of confirmed indicators; total ratios, ratios per function and compared ratios are shown. The following points are noteworthy.

Higher cost overruns does not lead to more indicators being confirmed. The trend lines for the project managers and the overall trend line actually decline slightly which means less indicators are confirmed for projects with higher cost overruns.

The designer has the highest confirmation ratios (Figure 10). This might be because in the case of GW the designer is closer to the process than the project managers.

The differences between the ratios of the project managers are considerable and remarkable at the same time. Even though their functions are similar one trend line is clearly lower than the other one (Figure 10). This might be caused by lack of communication or forgetting some things.

7.2 Discrepancies

To measure the inter-observer reliability Cronbach's alpha was used. The choice for this coefficient and its' calculations are explained in Appendix XII. Generally a reliability coefficient of 70% or higher is seen as acceptable but a reliability coefficient of 80% or higher is desirable. (Nunnally & Bernstein, 1994) Sometimes even a reliability coefficient of 60% for small data sets is seen as sufficient.

The outcomes of the calculations in Excel and SPSS are presented below.

Project	Cronbach's α
Banco Lafise	0,143
Cerveceria Hondureña	N/A
Aimar	0,879
Cigrah	0,822
Panaderia Jerusalen	0,914

Table 12 Cronbach's alpha

Cronbach's alpha for Banco Lafise is very low which means there is little internal consistency, again the same causes as presented above might be applicable. Also reliability here is a lot lower because only two persons have been interviewed.

The Cronbach's alphas for Aimar, Cigrah and Panaderia Jerusalen are all above 0,8 and thus it can be assumed that the inter-observer reliability is sufficient.

7.3 Alternate form reliability

The alternate form reliability tests internal consistency. By presenting the same assertions twice but differently formulated in one interview, the consistency of the interviewees answers can be analyzed. Further explication of this test can be found in Appendix XII. The outcomes are presented in Table 13. A reliability coefficient of 70% or higher is seen as acceptable.

	Project Manager 1	Project Manager 2	Designer	Averages
Banco Lafise	58%	100%	-	79%
Cerveceria	58%	83%	-	71%
Aimar	42%	83%	75%	67%
Cigrah	92%	100%	83%	92%
Panaderia	75%	100%	92%	89%
Averages	65%	93%	83%	80%

Table 13 Alternate form reliability outcomes

Only three values are below 70% and these turned out to be due to misunderstanding the assertion. The assertion was explained and the later results were better. An average reliability of 80% has been found, thus internal reliability is sufficient.

8 Avoiding rework

In previous chapters rework and its' causes in some projects of GW have been analyzed. Knowing what causes the problems is already a major step to avoiding them in the future. The causes identified and summarized in paragraph 6.6 can roughly be grouped into six categories; change orders, coordination, material deliveries, construction methods, personnel and machinery. In this chapter some recommendations on how to avoid these problems are given. The category machinery will not be discussed because this is mostly an external factor in GW's projects and is therefore not included in the scope.

8.1 Change orders

The following conclusion has already been drawn in Chapter 4.3.

Four out of five projects had to process change orders. These change orders resulted in increased revised contract values of up to 140% the initial values. The costs involved with these changes are passed on to the customers. So GW does not take on the direct costs of this rework but the indirect consequences mentioned in paragraph 3.3 are still applicable. Therefore change orders should also be avoided even though the direct costs are for the client.

From the interviews the most important causes of design changes have been identified as:

- A design change is initiated by the contractor
- A design change is initiated by the end user/occupier (changes in wishes/extra orders)
- A design change is initiated due to financial changes
- A design change is initiated due to economic changes

According to the interviewees changes in wishes and extra orders from clients were the most significant contributor to change orders and financial changes were mostly due to the financial situation of the client. In this paragraph information will be presented on how to avoid change orders or how to mitigate the consequences of change orders.

A change order by the client, often called a scope change, refers to when the owner of the property decides to add, remove, or relocate systems or equipment. Communication and coordination are the most important factors that cause scope changes. GW should have a clear view of the clients' wishes and goals from day one. On the other hand should the client have a clear view of the projects' progress at all times. Regular meetings are highly desirable to keep each other well informed.

As mentioned above it is very important to clarify the objectives and expectations of the client to ensure that they are understood from the clients' perspectives. Thus the briefing process at the start of a project is very important. (Kamara, Chimay, & Evbuomwan, 2002) Kamara et al. also provide some suggestions to improve the briefing process, namely:

- clarity in defining client requirements
- more involvement of various actors (client, architect, project manager)
- incorporation of clients' views in design phase
- take sufficient time for the briefing process

These tips were considered to be useful by GW when presenting the findings.

Many more tips could be given about how to make sure the end product meets the clients' wishes but a whole study could be devoted to this subject. This study will not go any further into the involvement of the client, the major point is the communication with the client.

If changes cannot be avoided, the following suggestions reduce the impacts of the change order (Levy, 2002):

1. Alert all project participants to be sensitive to all suspected changes in scope and report them to the project manager immediately.
2. Instruct the project superintendent to identify and document any potential changes in their daily report.
3. When a change in scope affecting the contract sum is identified, notify the architect and owner as soon as possible.
4. Any changes in scope of work or schedules reported from the field must be documented by referring to the drawing number and/or detail, finish schedule, specification section or name and position of person issuing verbal instructions to affect the change.
5. Do not let change order proposals stack-up and do not combine unrelated changes in one change order.
6. Do not wait until the end of the job to submit the change orders.
7. Note the impact on the schedule.
8. Determine whether any escalation costs ought to be included in the change order if the work will extend the projects' completion date or the work will be performed at a time increased labour and/or material costs may be incurred.
9. Schedule a post construction meeting and review all issued and missed change orders.

8.2 Lack of coordination

From the interviews it was also concluded that lack of coordination during the design phase was quite frequent and caused some problems. Coordination can be defined as the act of making all the people involved in a plan or activity work together in an organized way (Cambridge University, 2008). Coordination among project participants has been recognized as an important ingredient for success of many projects (Jha & Iyer, 2005). Coordination is generally seen as one of the functions of management. Management was not included in the scope of this project, therefore only a few important coordination activities, that relate to other problems identified earlier, will be described. Jha & Iyer identified the most important coordination activities for construction projects in India, the list can be found in Appendix XIII. As mentioned some of the activities are related to causes of rework or problems that have already been identified as areas of improvement in this research, such as:

- Arranging timely carrying out of all tests for inspections and approval by the engineers and maintaining records of the inspections (important to mitigate rework costs)
- Arranging remedial work methods and programs for executing in case of defect or damage (quick resolvement is important to mitigate rework costs)
- Analysis of the project performances on time, cost and quality and detecting variances with expected values (from financial analysis was concluded that the evaluation was not sufficient)
- Several activities related to personnel performance and involvement, such as ensuring discipline and motivation (identified as important rework cause)

- Several activities related to communication between involved parties, both internal parties (personnel) and external parties (e.g. client). Frequent meetings between different departments for example are very important for proper coordination.
- Agreement on detailed methods of construction with all the parties involved (identified as important rework cause)

8.3 Late material deliveries

Most of the analyzed projects had problems with late deliveries of materials. P.P.A. Zanen (2008) already concluded that the flow of material within GW could be improved. He also concluded that late material deliveries had a negative effect on labour costs. In this research it has been concluded that labour costs were often higher than estimated. M. ten Klooster (2009) studied material management within GW extensively and suggested several improvements as well as the implementation of a material codification system and computer program. The latest project analyzed (La Cerveceria, finished in 2010) did not undergo late material deliveries which might indicate that material management has improved since Ten Klooster's research. It is recommended to evaluate material management in the near future to see if this is the case and if not, have another good look at the recommendations made by M. ten Klooster.

8.4 Construction methods

From the interviews has been concluded that changes to construction methods have been made in most projects to improve constructability and most were due to site conditions. Choosing the appropriate construction method is of great importance to the success of a project. A change in construction methods can lead to time delays, cost overruns and many indirect consequences such as stress. The work preparation before the design and construction phase is very important. Several construction methods should be considered and compared by looking at their advantages and disadvantages. Aspects such as costs, reliability, availability of knowledge and equipment and applicability should be analyzed. An important aspect of applicability is the construction site. Analyzing the site conditions is an important part of work preparation. If it is not done correctly, the construction personnel might run into unexpected situations which might require design changes, changes in construction methods or might cause damage to the structure. And these are just a few of the possible consequences of poor analysis of site conditions. Take enough time to conduct the geotechnical analysis of the construction site to avoid running into surprising situations regarding site conditions.

When presenting my findings it was confirmed that the same designs are often used for different projects (in the case of residential projects). This might be possible if the underground is similar but it is likely that this is not the case. It is even possible that the underground is different for houses at just one project site. Always perform a geotechnical analysis and adapt the design if necessary.

8.5 Personnel

Several possible causes of rework regarding construction personnel have been confirmed. It was confirmed that construction personnel and sometimes engineers as well had made mistakes, had not complied to rules, slips and lapses of attention had occurred and damage had been caused by GW or a subcontractor at times.

From informal interviews it was found that in many projects faults such as cracks in walls, wrong placement of parts and broken tiles occur. Then, the subcontractors point towards each other and no one claims responsibility. GW then has to order a subcontractor to redo the work properly, and pays the costs.

These faults can have many origins. Lack of workmanship does not seem to be the major cause since this has been tested in the surveys as well. Negligence, lack of motivation or lack of communication might be more common causes. The causes have not been further studied since it was not included in the scope of the project and time did not permit to analyze a project on a day to day basis. In the next chapter however will be presented how performance of the construction personnel can be evaluated in future projects to learn what aspects need improvement.

Most construction personnel is hired with the subcontractors and it is therefore very difficult to change for example the attitude of the construction workers. This should be the responsibility of the subcontractors manager, but there are some things that GW might be able to do to improve the productivity of the workers.

- Making the subcontractors and their employees realize that if they produce bad work, they will lose potential future work and thus income, might be a start to a better mentality or motivation. For example meetings for all personnel and regular subcontractors can be arranged, where the companies goals and expectations are presented.
- A very clear briefing before start of the work for all the workers (and not just the subcontractors manager) might give the construction workers a better understanding of their tasks and of what is expected of them.
- Regular inspections and evaluations by the engineers on site make it harder for subcontractors to point to each other. Errors or damage can be attributed to a specific subcontractor.

But the most effective might be hiring subcontractors with whom good experiences have been had in finished projects. How can be learned from finished projects will be described in the next chapter.

During the presentation of my findings, the head-designer confirmed that the idea about meetings is something GW has been planning to implement for a while and she saw potential in doing so. These suggestions were well received.

9 Inter-project learning & project evaluation

P.P.A. Zanen (2008) already suggested that because of many similarities between projects, GW can use the experiences of finished projects to improve future projects. He states the following:

"In the process of monitoring and controlling a construction project or parts of a project such as an individual house, information is gathered and knowledge is created. This knowledge can be used to improve control in the later stages of the specific project, but it can also be used in future projects that suffer from similar issues. Corrective actions in one project provide information on effectiveness that can be used to assess possible actions when a similar issue arises in a future project. Looking at the profile of GW's current projects there are a great number of similarities, not only in the project characteristics, but also in the issues and problems. Furthermore, suppliers and subcontractors are often shared between projects and so knowledge and experiences regarding those aspects can be shared between projects as well. By establishing these processes and making sure that information is stored and used in the future, inter-project learning can become part of the project operations of GW and the knowledge can be disseminated through the organization and between projects."

Adopting inter-project learning enables an organization to identify ways to progressively generate, share and imbed new knowledge, for the benefit of both the projects and the permanent organization (Antoni, 2000).

To be able to properly learn from finished projects or even during the project, projects should be properly evaluated. Currently evaluation is rather poor, for example the evaluation at the end of the project only consist of a financial analysis. Events that occur on the construction site for example are not written down. This because extensive regular evaluations take too much time according to personnel on site. Therefore evaluation methods proposed should also be kept simple. Only evaluation of rework events has been studied, since this research focuses on that specific aspect of failure costs. Evaluation should include a lot more than just rework but that is not the scope of this research.

In this chapter propositions on how to evaluate rework during a project to be able to mitigate its effect in later phases of the same project or to avoid the effects in future projects is described. A standard form has been made to report rework or other relevant events and these reported events should be processed into a Microsoft Acces database, for which a standard set-up has also been made. Furthermore it is explained how the model used earlier in this research to identify causes of rework, can be used in future projects to monitor or evaluate the project.

9.1 Reporting rework events

To gain more insight into the identified rework causes, as well as yet unidentified rework causes, rework should be analyzed for every project in the future. For the whole construction business it has been concluded that rework events are often scarcely communicated to top level management. And due to lack of information no change in procedures is made and the same defect might reoccur in a future projects (Arditi & Gunaydin, 1997). If the project is evaluated properly, feedback can be given to many aspects of the construction process and repetition of the events can be avoided.

If events are not reported and written down, it is certain that things will be forgotten and as George Santayana (1905) said: "Those who cannot remember the past, are condemned to repeat it." The project team must monitor information about the problems encountered during the project. In doing

this collection of problems, team members must be willing to share experiences and tell the truth about any problems (Kotnour, 2000).

The first step in adopting inter-project learning in GW is therefore starting to report and monitor erroneous events such as rework. The problems that are encountered and their consequences and causes should be written down. A standard form to do so, has been made. Also a standard database in Microsoft Access has been made in which these forms can then be processed. These standard forms make reporting and analyzing the problems easier and less time consuming. When a rework event happens in either the design or construction phase it should be reported by using the paper form. This should be done by at least the engineer in charge at the construction site and the designer. The forms should then be processed in Microsoft Access. This should be done by one person to make sure that *all* events per project are reported in *one* database. The digital database makes sharing the information easier and provides a more clear view of the situation. The database can then be discussed weekly or monthly depending on the amount and gravity of the events. At the end of the project all the rework events can be summarized. This gives a better understanding of the projects' problems, their causes and their consequences. It can also be seen as a performance report of the personnel. For example, it can be noted if a specific subcontractor caused many rework events. This should be a learning experience, and for future projects another subcontractor should be hired.

Aspects that should be described for every rework event are (Love & Irani, 2002b):

- What was the problem?
- What or who was the cause?
- What part of construction/What subcontractor?
- How can it be classified?
- How did it affect time?
- How did it affect costs?

In the online help section of Microsoft Access a standard database for issue reporting was available. This issue-database set-up itself was not sufficient but it did give some additional ideas for the database set-up that has been developed. The paper form and Access database can be found in Appendix XIV, where the use of the database will be explained into detail as well.

The use of these tools in future projects is highly recommended to be able to learn from finished projects and by doing so improving future projects. With these tools communication will also be improved and this will speed up resolving the issues. The time necessary to implement these tools should not be seen as an expense but as an investment.

The suggestion of reporting rework events and setting up a database was very well received by the people that were present during the presentation of the findings at the end of the study. Everyone saw its potential.

9.2 Rework monitoring checklist

Within GW it is usual that a project team meets once every week to discuss the project's progress. Meeting once every week with all the involved people is very good, but unfortunately there is a lack of evaluation tools. Because of this lack of evaluations tools or evaluation reports (such as rework reports), events might be forgotten and therefore are not discussed at these weekly meetings. During a project rework events should be communicated to the whole project team as soon as possible and the database described above should improve the communication but it might be the case that rework events have not yet been processed. Therefore a very simple tool has been made that should improve monitoring the rework events during a project.

In the first stages of this research a model has been made that functioned as a checklist to analyze what the main causes of rework within GW were. This model can also be used to analyze rework causes during projects. Based on this model a checklist has been set up. This checklist is slightly different from the original list of rework causes. To make sure that the checklist was not too elaborate (and thus more time consuming), some causes have been grouped. This has mainly been done for causes less frequently confirmed during the interviews.

The evaluation checklist form presents statements (similar to the ones presented during the interviews) which then should be confirmed or denied. If they are confirmed, it indicates a rework event has happened, is happening or might happen in the near future. By filling in this checklist weekly, rework can be identified, communicated and resolved quickly. The main idea is that it functions as a reminder tool. Statements that are answered with "agree" are the ones that should be discussed at the next meeting. It should be filled in by at least the designer and the person in charge at the construction site. The form can be found in Appendix XV.

10 Conclusions & recommendations

In paragraph 1.2 the main objective of this research has been defined as: "*To assess rework costs in construction projects of Grupo Williams and suggest improvements to reduce these rework costs".* To reach this objective research questions have been formulated in paragraph 1.3. After the theoretical study and the research into GW's processes these research questions can be answered and conclusions will be drawn in paragraph 10.1. From the conclusions several recommendations for improvements have been drawn and these are presented in paragraph 10.2. Besides these scope-related recommendations some general conclusions have been drawn as well. These conclusions and the related recommendations (also for possible future studies) are presented in paragraph 10.2 as well.

10.1 Conclusions

In this paragraph the research questions to reach the main objective are answered. This is done per sub-objective as presented in paragraph 1.2. Furthermore will references be given to the chapters or paragraphs where more detailed information can be found.

Assessment of rework costs in construction projects of GW

The following questions are the research questions that were tried to be answered during the first phase of this research.

- How much rework costs occur at projects of GW?
- What or who causes the rework?
- How is the rework classified?
- How did the rework affect time?

The assessment of rework costs was done by analyzing five realized projects. Unfortunately the analysis did not present all the desired information due to missing data. But the most important aspect, getting an impression of the amount of rework costs, was realized.

Average total cost overrun (average failure costs) of the five projects was 13%. The highest total cost overrun was 54% (L. 3.664.231,51). Both labour and material costs contributed to these cost overruns. Material cost overruns were as high as 59% (L. 1.753.071,33) and labour costs were even found to be 232% (L. 5.527.909,76) higher for one project. These overruns are total failure costs and are not all due to rework events. Because rework events have not been reported at all for these projects it was very hard to determine the actual amount of rework costs. Nevertheless the percentage of failure costs that is due to rework events has been estimated based on numbers about change orders. For one project 86% (L. 3.142.469,27 and probably even more) of total cost overruns could be attributed to rework. However it is important to note that not all these costs are for GW, many are passed on to the client. Though the costs are passed on, this is an undesirable situation. It can be concluded that rework costs are very severe in some projects and make up a major part of the failure costs in GW's projects. See Chapter 4 for more detailed information.

About the causes and classification of the rework events not much could be concluded after the analysis of financial documents. Just that change orders were very frequent and revised contract values were up to 140% the initial value. Conclusions about the causes and classification could be

drawn after the interviews, see the next sub-objective. About the effect of rework on time nothing could be concluded due to the absence of this information.

Determination of the most relevant rework causes

The second sub-objective was determining the most relevant rework causes. The following questions were answered by interviewing personnel that was involved in the projects:

- What causes most of rework?
- What causes the highest rework costs?
- Which causes should be taken on?

In the interviews rework indicators were checked for their occurrence in the projects. The most frequently occurring causes of rework are:

Design-phase

- A design change is initiated by the contractor
- A design change is initiated by the end user/occupier
- A design change is initiated due to financial changes
- A design change is initiated due to economic changes
- Lack of co-ordination

Construction-phase

- Changes in clients' wishes
- Extra orders by client
- Machine breakdown or defects
- Machine not working satisfactorily
- Late deliveries of materials
- A change in construction methods in order to improve constructability
- A change in construction methods due to site conditions
- Mistakes in executing rules
- Noncompliance of rule
- Slips/lapses of attention
- Damage caused by GW or a subcontractor

After the interviews the causes could also be categorized, which answers a previous question: 50% is change-related, 37% is error-related and 13% falls into another category.

Change orders were already identified as a major rework cause in the first phase and this was confirmed in the interviews, according to the interviewees change orders were actually the biggest cost overrun cause.

Most of these causes are within GW's own scope or GW can greatly influence them. These are also the causes that should be taken on, and by doing so they can be avoided in future projects. Rework events related to machinery are a lot harder for GW to control because they are mostly external. See Chapter 6 for a more elaborate description of the rework causes.

To suggest improvements to reduce these rework costs

The last part of this research consisted of suggesting improvements to avoid the identified causes in future projects and suggesting ways for GW to learn from their projects. The following research questions were answered to reach those objectives:

- How can the causes of rework be reduced or avoided completely?
- How can GW implement the suggested improvements?
- How can GW learn from projects to reduce rework costs in the future?

The rework causes could be grouped into the following groups; change orders, lack of coordination, late material deliveries, construction methods and personnel. For each of these grouped causes suggestions have been made on how to avoid them in the future. Repeating all the suggestions here would be redundant, Chapter 8 describes how to avoid these rework causes in the future.

If GW wants to learn from their mistakes they should adopt inter-project learning more strictly. Inter-project learning (in this research only learning from rework events was studied) can only be successful if the rework events are properly evaluated. And to be able to properly evaluate rework events it is necessary that the events are written down and reported. Therefore a standard form to report rework events has been made. These forms can then be processed into a Microsoft Access database for which a standard set-up has also been made. These forms and the digital database allow proper evaluation and provide information about rework so that in the future they can be avoided.

To quickly resolve rework it is important that the events are quickly discussed and evaluated. A simple tool has been developed that allows proper monitoring. In a standard form, assertions are presented and by answering these assertions, possible rework events can be identified. Filling in and discussing this form in the weekly meetings should improve monitoring rework during a project and make evaluation easier. This evaluation tool and the database are described in Chapter 9.

10.2 Recommendations

Now conclusions have been drawn, some recommendations can be given. During the research not only issues regarding rework were discovered, some recommendations about these other issues will also be given. Last some research possibilities for future studies will be presented.

10.2.1 Avoiding rework

In Chapter 8 improvements were suggested for the most important activities that cause rework in GW's projects. The activities were grouped into the following categories:

- Change orders
- Lack of coordination
- Late material deliveries
- Construction methods
- Personnel

The suggested improvements are based on theory about how these activities are ideally carried out. The current processes within GW regarding these activities have not been analyzed, because that would have been too time-consuming. Some aspects of these suggestions might therefore not fully

apply to GW or perhaps they have already been introduced in the company. I recommend arranging a meeting with involved personnel where these activities are discussed. Based on these discussions and the suggestions made in this report, you can decide what actions should be taken to avoid or at least mitigate rework events. Knowing what causes problems is already a big step in the good direction but now actions have to be taken to actually prevent them from happening again.

10.2.2 Reporting rework & database

In Chapter 9 is explained why inter-project learning can be valuable to GW and how it can become part of GW's processes. The first step in adopting inter-project learning (regarding rework) is starting to report rework events. A standard report form has been made, which makes reporting and processing the events into the digital database easier. The Microsoft Access database, for which a standard set-up has also been made, should be managed by one person to make sure that *all* events per project are reported in *one* database. The digital database makes sharing the information easier and provides a more clear view of the situation. This provides a better understanding of the projects' problems, their causes and their consequences. Construction-personnel performance was proven to be one of the major rework causes and a database like this makes personnel performance evaluation easier as well.

The use of this tool in future projects is highly recommended to be able to learn from finished projects and by doing so improving future projects. The time necessary to implement the database should not be seen as an expense but as an investment. A detailed explanation on the use of the database can be found in Appendix XIV.

Before implementing the database it is of great importance that the personnel tasked with reporting rework events understands the need of complete and correct reports. It is most likely impossible to report all rework events. Some might for example not even reach any of GW's personnel because a subcontractor does not communicate them. But as many events as possible should be reported to gain a full and correct insight in the problems. This also means that more regular inspections have to be carried out by the engineers in charge at the construction site. The Microsoft Access set-up has not been tested in a pilot-project yet. It is wise to test the use of the database in a pilot project, this might make full implementation afterwards smoother since some personnel already has gained experience.

10.2.3 Rework monitoring checklist

Besides the rework database a rework monitoring checklist has been made. This checklist presents statements which can be confirmed or denied. If they are confirmed, it indicates a rework event has happened, is happening or might happen in the near future. By filling in this checklist weekly, rework can be identified, communicated and resolved quickly. The main idea is that it functions as a reminder tool. Statements that are answered with "agree" are the ones that should be discussed at the next meeting. The form can be found in Appendix XV.

10.2.4 Financial evaluation & accountancy

Besides all the conclusions drawn and recommendations made regarding rework, some other areas of improvement were also found during this research. During the first weeks of this research financial documents of GW's projects have been studied. These studies provided less information as desired, and the information that was derived was often less-reliable. This was mainly due to the following reasons (for detailed explanation, see paragraph 4.4):

- There is hardly any uniformity between the balance sheet drawn up by the department of presupuestos and the numbers from the accounting department (contabilidad). If there is uniformity it is almost impossible to trace due to different layouts, structures and codifications. At times the costs in the balance sheet were a lot higher than those registered by the accounting department, but for other projects the balance sheet numbers were a lot lower than the ones from accounting. Especially the latter is dangerous since it might happen that everyone assumes the company made a profit while it actually made losses.
- The accounting department is not able to provide an overview of the total financial situation of a project. There should be an overview that gives an idea about the projects' financial situation at a glance. It might even be better to make the accounting department responsible for drawing up the balance sheets.
- The way projects are being evaluated, specifically the way the balance sheet is drawn up, is not standardized. To be able to evaluate projects properly a standardized way of drawing up the balance sheet should be adopted. It makes it easier to draw up the balance sheets, it is easier to trace costs and a summary of the projects results can be provided at a glance.

Inadequate accountancy can be very dangerous. The company might endure losses without even knowing it. In less profitable times errors like these show up at the end of the year and if it happens on a larger scale it might even mean the bankruptcy of a company. Since the scope of this research did not include financial evaluation processes and my knowledge on accounting is limited I did not look into this further. Therefore it is highly recommended that GW properly evaluates the processes regarding the financial evaluation of projects. The cause of lack of uniformity should be found to make sure balance sheets are reliable in future projects. The accounting department should be able to give a proper overview of the financial situation of a project at all times and to be able to do this a standard balance sheet set up has to be made. Numbers from the balance sheet should be traceable by using the same codification as the accounting department.

10.2.5 Work preparation

A possible future research area might be work preparation for GW's projects. From the interviews it was found that quite some rework causes are related to the work preparation phase. Rework due to change orders or changes in construction methods for example can largely be avoided if work is prepared correctly. Reviewing how work is prepared, should be done anyhow as explained in 10.2.1 but it might be an interesting subject for future studies since the work preparation phase consists of a lot more than the aspects described in the change order and construction method improvements sections.

10.2.6 Other failure costs

As explained in the theoretical section, rework costs are only part of total failure costs. Even though it was found that rework costs make up a large part of failure costs in GW, it would be very wise to study other failure costs as well. Other failure costs might be slightly more difficult to identify however. Rework is a direct failure cost which is well identifiable. Examples of other failure costs (direct or indirect) are costs of late construction completion, loss of future clients, loss in productivity, material waste or warranty claims.

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Appendix I: Model

	Phase	Type	Cause	Code	Source
Rework	Design	Error	Lack of co-ordination	DE1	Josephson et al (2002)
			Unsuitable design	DE2	Josephson et al (2002)
			Design is hard to construct	DE3	Josephson et al (2002)
			Faulty design	DE4	Josephson et al (2002)
			Incomplete drawings	DE5	Josephson et al (2002)
			Erroneous drawings	DE6	Love & Sohal (2003)
			Not enough time to design (given by contractor)	DE7	Love & Sohal (2003)
		Change	A design change is initiated by the contractor	DC8	Love & Sohal (2003)
			A design change is initiated by the end user/occupier	DC9	Love & Sohal (2003)
			A design change is initiated by a supplier	DC10	Love & Sohal (2003)
			A design change is initiated by Grupo Williams	DC11	Love & Sohal (2003)
			A design change is initiated due to financial changes	DC12	Love et al (2000)
			A design change is initiated due to economic changes	DC13	Love et al (2000)
			A design change is initiated due to social changes	DC14	Love et al (2000)
			A design change is initiated due to legal changes	DC15	Love et al (2000)
		Other	Communication problems	DO16	Love et al (2003)
			Interpretation problems	DO17	Love et al (2003)
	Construction	Error	Omission errors by construction personnel	CE-E18	Love et al (2009)
			Mistakes in executing rules	CE-E19	Love et al (2009)
			Noncompliance of rule	CE-E20	Love et al (2009)
			Slips/lapses of attention	CE-E21	Love et al (2009)
			Erroneous workmanship	CE-E22	Josephson et al (2002)
			Faulty material handling	CE-E23	Josephson et al (2002)
			Faulty machine handling	CE-E24	Josephson et al (2002)
			Insufficient cleaning	CE-E25	Josephson et al (2002)
			Damage caused by GW or a subcontractor	CE-E26	Love & Sohal (2003)
			Inexperienced personnel	CE-E27	Love & Sohal (2003)
			Late deliveries of materials	CE-S28	Josephson et al (2002)
			Faulty manufacturing of materials	CE-S29	Josephson et al (2002)
			Material hard to work with	CE-S30	Josephson et al (2002)
			Delivery with wrong type of materials	CE-S31	Josephson et al (2002)
			Mistakes in planning	CE-M32	Josephson et al (2002)
			Faulty work preparation	CE-M33	Josephson et al (2002)
			Faults in materials administration	CE-M34	Josephson et al (2002)
			Wrong setting up	CE-M35	Josephson et al (2002)
		Change	Changes in clients' wishes	CC-C36	Josephson et al (2002)
			Bad choice of material by client	CC-C37	Josephson et al (2002)
			Extra orders by client	CC-C38	Josephson et al (2002)
			Wrong information given by client	CC-C39	Josephson et al (2002)
			A change in construction methods in order to improve constructability	CC-E40	Love & Sohal (2003)
			A change in construction methods due to site conditions	CC-E41	Love & Sohal (2003)
		Other	Machine not working satisfactorily	CO-E42	Josephson et al (2002)
			Machine breakdown or defects	CO-E43	Josephson et al (2002)
			Damage due to weather conditions	CO-D44	Love & Sohal (2003)
			Damage due to natural disasters	CO-D45	Love et al (2000)

Table 14 Model including literature sources

Appendix II: Financial analysis proyecto Banco Lafise

	Actual			Estimated		Difference	%
Materials	5.152.847,57						
Freight	341.274,31						
Total	5.494.121,88			4.341.685,59		1.152.436,29	27%
Labor	1.701.768,88			3.986.840,12		-2.285.071,24	-57%
Topografia	24.750,00			42.000,00		-17.250,00	-41%
Overtime costs	12.943,53			0		12.943,53	
Total	1.739.462,41			4.028.840,12		-2.289.377,71	-57%
Indirect costs	649.386,79			834.659,77		-185.272,98	-22%
Total costs	7.882.971,08			9.205.185,48		-1.322.214,40	-14%
	Start	End	Days	Start	End	Days	
Time	N.A.	N.A.	N.A.	4-11-2008	18-2-2009	107	
Total contract value (initial)	Total contract value (End)	% Change					
L. 10.068.315,57	L. 11.461.453,73	12%					

Table 15 Financial analysis proyecto Banco Lafise

Appendix III: Financial analysis proyecto Cerveceria Hondureña

	Actual			Estimated		Difference	%
Materials	3.293.597,68						
Others & freight	523.481,12						
Total	3.817.078,8			4.488.389,39		-671.310,59	-15%
Labor	2.872.988,94			2.723.402,09		149.586,85	5%
Others	200.136,88						
Topografia	41.000,00			38.400,00		2.600,00	7%
Overtime costs	6.791,90			0		6.791,9	
Total	3.120.917,72			2.761.802,09		359.115,63	13%
Indirect costs	601.119,49			1.179.435,37		-578.315,88	-49%
Total costs	7.539.116,01			8.429.626,85		-890.510,84	-11%
	Start	End	Days	Start	End	Days	
Time	N.A.	N.A.	N.A.	19-10-2009	15-2-2010	120	
Total contract value (initial)	Total contract value (End)	% Change					
L. 9.242.395,75	L. 9.242.395,75	0%					

Table 16 Financial analysis proyecto Cerveceria Hondureña

Appendix IV: Financial analysis proyecto Aimar

	Actual			Estimated		Difference	%
Materials	4.907.634,08						
Others & freight	297.988,42						
Total	5.205.622,5			7.140.220,77		-1.934.598,27	-27%
Labor	2.657.547,42			4.004.856,35		-1.347.308,93	-34%
Topografia	0,00			18.000,00		-18.000,00	-100%
Overtime costs	26.750,02			0		26.750,02	
Total	2.684.297,44			4.022.856,35		-1.338.558,91	-33%
Indirect costs	1.184.420,93			457.931,02		726.489,91	159%
Other costs	1.452.287,97						
Total costs	10.526.628,84			11.621.008,14		-1.094.379,30	-9%
	Start	End	Days	Start	End	Days	
Time	1-9-2007	29-2-2008	182	15-5-2007	3-12-2007	145	26%
Total contract value (initial)	Total contract value (End)	% Change					
L. 13.997.163,46	L. 14.276.532,02	2%					

Table 17 Financial analysis proyecto Aimar

Appendix V: Financial analysis proyecto Cigrah

	Actual			Estimated		Difference	%
Materials	2.340.979,94						
Others & freight	19.000						
Total	2.359.979,94			4.426.865,64		-2.066.885,7	-47%
Labor	7.911.606,64			2.383.696,88		5.527.909,76	232%
Total	7.911.606,64			2.383.696,88		5.527.909,76	232%
Indirect costs	203.207,45			N.A.		#WAARDE!	#WAARDE!
Total costs	10.474.794,03			6.810.562,52		3.664.231,51	54%
	Start	End	Days	Start	End	Days	
Time	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	
Total contract value (initial)	Total contract value (End)	% Change					
L. 7.810.408,99	L. 10.952.878,26	29%					

Table 18 Financial analysis proyecto Cigrah

Appendix VI: Financial analysis proyecto Panaderia Jerusalen

	Actual				Estimated		Difference	%
Materials	4.712.609,47							
Others & freight	0							
Total	4.712.609,47				2.959.538,14		1.753.071,33	59%
Labor	2.363.380,73				1.998.310,49		365.070,23	18%
Topografia	N.A.				13.500,00		#WAARDE!	
Overtime costs	N.A.				0		#WAARDE!	
Total	2.363.380,73				2.011.810,49		351.570,24	17%
Indirect Costs	642.488,34				366.509,13		275.979,21	75%
Total costs by Proj. Man.	7.075.990,20							
Total costs incl. Indirects	7.718.478,54				5.337.857,76		2.380.620,78	45%
	Start	End	Days		Start	End	Days	
Time	N.A.	N.A.	N.A.		N.A.	N.A.	N.A.	
Total contract value (initial)	Total contract value (End)	% Change		**Estimated profit**	**Realized profit**	% Change		
L. 6.048.575,33	L. 7.265.446,26	20%		L. 710.717,57	L. -453.032,28	-164%		

Table 19 Financial analysis proyecto Panaderia Jerusalen

Appendix VII: Interview assertions

The assertions have been translated to Spanish since some interviewees spoke deficient English. Some assertions have been presented twice but in other words to test the interviewees attention. As many assertions as possible have been presented in a positive way i.e. avoiding presenting the assertion as a personal error. By doing so it is avoided that people feel personally offended and might not answer the questions honestly or refuse to take part in the questionnaire.

Code	Assertion
DE1	The coordination during the design phase was good La coordinación en la fase de diseño fue sin problemas
DE2	The design was suitable for the projects' purposes El diseño era adecuado para los propósitos del proyecto
DE3	The design was easy to construct Construir el diseño estaba fácil
DE3	The design was hard to construct Construir el diseño estaba difícil
DE4	The design was flawless El diseño estaba impecable
DE4	The design contained errors El diseño contenía errores
DE5	The design drawings were complete Los dibujos de diseño estaban completos
DE6	The design drawings were flawless Los dibujos de diseño estaban impecable
DE7	The designer had been given sufficient time to complete the design El diseñador había tenido tiempo suficiente para completar el diseño
DC8	Design changes were initiated by the contractor Cambios de diseño estaban iniciadas por el contratista
DC9	Design changes were initiated by the end user or occupier Cambios de diseño estaban iniciadas por el usuario final u el ocupante
DC10	Design changes were initiated by a supplier Cambios de diseño estaban iniciadas por un proveedor de materiales
DC11	Design changes were initiated by Grupo Williams Cambios de diseño estaban iniciadas por Grupo Williams
DC12	Design changes were initiated due to financial changes Cambios de diseño se inició debido a los cambios financieros
DC13	Design changes were initiated due to economic changes Cambios de diseño se inició debido a los cambios económicos
DC14	Design changes were initiated due to social changes Cambios de diseño se inició debido a los cambios sociales
DC15	Design changes were initiated due to legal changes Los cambios de diseño se inició debido a los cambios legales
DO16	Communication about the design was good La comunicación sobre el diseño estaba bueno
DO17	Interpretation regarding the design was good Interpretación sobre el diseño estaba bueno
CE-E18	Construction personnel forgot things or tasks Personal de construcción olvidaba cosas o tareas

CE-E18	Construction personnel completed all tasks they were given Personal de construcción completaban todas las tareas que se les dio
CE-E19	Mistakes in executing tasks were made during construction Durante la construcción errores en la ejecución de las tareas estaban realizado
CE-E19	Construction personnel completed the tasks correctly Personal de construcción completó las tareas correctamente
CE-E20	Rules were not followed during construction Reglas no estaban seguido durante la construcción
CE-E21	Slips or lapses of attention of the personnel occurred Resbalones o lapsos de atención del personal causaron errores
CE-E22	Lack of workmanship caused errors Falta de habilidad profesional causó errores
CE-E22	The construction personnel had many skills El personal de construcción tenía muchas habilidades
CE-E23	Construction personnel handled the materials correctly Personal de construcción trató a las materiales correctamente
CE-E24	Construction personnel handled the machinery correctly Personal de construcción trató a las machinas correctamente
CE-E25	The construction site was sufficiently cleaned El emplazamiento de la obra estaba limpiada suficientemente
CE-E26	Damage was caused by Grupo Williams or a subcontractor Daño estaba causado por el Grupo Williams o un subcontratista
CE-E27	The construction personnel was inexperienced El personal de la construcción no tenía experiencia
CE-S28	Materials were delivered too late Materiales estaban entregado demasiado tarde
CE-S29	Materials were faulty manufactured Materiales estaban fabricado con defectos
CE-S30	Materials were hard to work with Estaba difícil trabajar con algunos materiales
CE-S31	Wrong materials were delivered Materiales malas se entregaron
CE-M32	The planning was correct La planificación estaba correcta
CE-M33	Work had been prepared correctly El trabajo se había preparado correctamente
CE-M34	Faults had been made in materials management Fallas se habían hecho en la gestión de materiales
CE-M35	The set-up at the construction site was good La puesta a punto al emplazamiento de la obra estaba buena
CC-C36	Changes in the clients wishes had to be processed Cambios en los deseos del cliente tenía que ser procesada
CC-C36	The client did not order any changes to be processed El cliente no ordenó ningún cambio para ser procesado
CC-C37	A bad choice of materials had been made by the client Una mala elección de los materiales se han hecho por el cliente
CC-C38	Extra orders have been made by the client El cliente he hecho órdenes adicionales
CC-C39	Wrong information has been given by the client Información errónea ha sido facilitada por el cliente

CC-E40	A change in construction methods in order to improve constructability was made Un cambio en los métodos de construcción con el fin de mejorar la constructibilidad se hizo
CC-E41	A change in construction methods due to site conditions was made Un cambio en los métodos de construcción debido a las condiciones del lugar se hizo
CO-E42	Machinery was not working satisfactorily Maquinaria no estaba funcionando de manera satisfactoria
CO-E43	Machinery breakdowns and defects happened Maquinaria averías y defectos pasaron
CO-D44	Weather conditions caused damage El tiempo causó daños
CO-D45	Natural disasters caused damage Desastres naturales causaron daños

Table 20 Overview of interview assertions in English and Spanish

Appendix VIII: Interview example

Survey rework costs Grupo Williams

Interviewer: Y.C. Mastenbroek

Interviewee:

Function:

Date:

Project:

Introduction

To conclude my Bachelor studies in Civil Engineering at the University of Twente I am currently carrying out my internship at Grupo Williams. I am researching the occurrence of rework in the projects of Grupo Williams. Rework can be defined as "the unnecessary effort of re-doing a process or activity that was incorrectly implemented the first time". The goal of this research is to assess rework costs in construction projects of Grupo Williams and suggest improvements to reduce these rework costs. The goal of this survey is to determine the causes of rework in five realized projects. By finding the causes and learning from them, improvements can be suggested so that rework costs can be reduced in future projects.

In this survey assertions will be presented, all of them represent a possible rework cause. You can then choose to which extend you agree or disagree with the assertion. The answer possibilities are; strongly agree, agree, undecided, disagree, strongly disagree and do not know. Choosing "undecided" means you do not agree but do not disagree either. If you do not know the answer or the assertion is not applicable to your position, choose "do not know". The surveys have already been adapted to your position to avoid answering many assertions that are not related to your position.

This survey will help me to conduct my research and help Grupo Williams gain insight in rework occurring at their projects and reducing its occurrence in future projects. Your answers will be handled confidentially. This survey does not try to point out personal errors but tries to improve the general construction process. It is of great importance that your answers are truthful.

The survey will probably take about 20 minutes per project. If you are interested in further information or the final results, you can always send an e-mail or ask for it in person, for contact information see below.

Thanks in advance,

Y.C. Mastenbroek
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DE1. The coordination during the design phase was good

Strongly disagree	Disagree	Undecided	Agree	Strongly agree	Do not know
☐	☐	☐	☐	☐	☐

DE2. The design was suitable for the projects' purposes

Strongly disagree	Disagree	Undecided	Agree	Strongly agree	Do not know
☐	☐	☐	☐	☐	☐

DE3. The design was easy to construct

Strongly disagree	Disagree	Undecided	Agree	Strongly agree	Do not know
☐	☐	☐	☐	☐	☐

Appendix IX: Interview example II (Spanish version)

Since the layout is exactly the same only the introduction has been added.

Introducción

Para concluir los tres primeros años de mis estudios en ingeniería civil en la Universidad de Twente estoy haciendo mi práctica en Grupo Williams. Estoy estudiando la aparición de "trabajo refundido" en los proyectos de Grupo Williams. Trabajo refundido se puede definir como "el esfuerzo innecesario de volver a hacer un proceso o actividad que se llevó a cabo incorrectamente la primera vez". El objetivo de mi práctica es evaluar los costos de trabajo refundido en los proyectos de Grupo Williams y después sugerir mejoras para reducir estos costos. El objetivo de este encuesta es determinar las causas de trabajo refundido en cinco proyectos realizados. Al encontrar las causas y aprender de ellos, se pueden sugerir mejoras a fin de que los costos de trabajo refundido se puede reducir en proyectos futuros.

En este encuesta proposiciones serán presentados, todos ellos representan una causa posible de trabajo refundido. Después puede elegir si usted está de acuerdo o en desacuerdo con la proposición. Los posibilidades de respuesta son totalmente de acuerdo, de acuerdo, indecisos, en desacuerdo, totalmente en desacuerdo y no sé. Cuando se elige "indecisos" significa que usted no está de acuerdo, pero no está en desacuerdo tampoco. Si usted no sabe la respuesta o si la proposición no es aplicable a su posición, elige la opción "no sé". Las encuestas ya se han adaptado a su posición para evitar contestar a muchas proposiciones que no están relacionados a su posición.

Esta encuesta me ayudará a hacer mi practica y ayudará a formar una idea de costos de trabajo refundido en los proyectos de Grupo Williams y reducir estos costos en proyectos futuros. Sus respuestas serán tratados de forma confidencial. Esta encuesta no trata de señalar errores personales, pero trata de mejorar el proceso de construcción en general. Es de gran importancia que sus respuestas sean veraces.

La encuesta, probablemente tomará aproximadamente 20 minutos por proyecto. Si usted está interesado en obtener más información o los resultados finales, siempre puede enviar un e-mail o preguntarme en persona.

Gracias de antemano,

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Appendix X: Confirmed indicators per project

In this Appendix the identified indicators per project will be presented in tables. These are the direct outcomes of the interviews. An explanation and further clarification per project can be found in Chapter 6.

Banco Lafise

A total of 23 out of 45 indicators has been confirmed for Banco Lafise. The identified indicators can be found in Table 21. For this project only two people have been interviewed. Since the design was made by another company in Nicaragua the designer could not be interviewed. 12 Indicators in the design phase have been confirmed and 11 in construction.

Frequency						Total		
2	DE4	DE5	DE6	DC8	DC9			
	CC-C36	CC-C38	CC-E40	CO-E43		9		
1	DE1	DE2	DC11	DC12	DC13			
	DO16	DO17	CE-E18	CE-E19	CE-E20			
	CE-E21	CE-E26	CE-S28	CC-E41		14	Design	Construction
						23	12	11

Table 21 Confirmed indicators Banco Lafise

La Cerveceria Hondureña

In proyecto Cerveceria 16 out of 45 indicators have been confirmed, see Table 22. The designer could not be interviewed for this project either. Only 3 indicators regarding the design have been confirmed, while 13 for the construction phase have been found applicable.

Frequency						Total		
2	DE1	DC9	CE-E21	CC-C36	CO-E43	5		
1	DC8	CE-E19	CE-E20	CE-E22	CE-E26			
	CE-E27	CC-C38	CC-C39	CC-E40	CC-E41			
	CO-E42					11	Design	Construction
						16	3	13

Table 22 Confirmed indicators Cerveceria Hondureña

Aimar

Again 16 indicators have been confirmed of which 5 design-related and 11 construction-related, see Table 23. Two project managers and the head designer have been interviewed for this interview.

Frequency						Total		
3	DC9	DC12	CC-C38			3		
2	CE-E19	CE-E21	CE-S28	CC-C36	CC-E40			
	CC-E41	CO-E42	CO-E43			8		
1	DC8	DC10	DC13	CE-E18	CE-E20	5	Design	Construction
						16	5	11

Table 23 Confirmed indicators Aimar

Cigrah

A total of 19 indicators have been identified for proyecto la Cigrah (Table 24), again two project managers and the head designer have been interviewed. In this project there are many discrepancies since 13 of the 19 found indicators have only been confirmed by one person. Many design related indicators, 11 in total, have been identified (mostly by the head designer) and 8 indications were confirmed for the construction process.

Frequency						Total		
3	DC9	CC-C36				2		
2	DE3	DC12	DC13	CC-C38	CO-E43	5		
1	DE1	DE4	DE5	DE6	DE7			
	DC8	DC10	CE-E26	CE-S28	CC-E40			
	CC-E41	CO-E42				12	Design	Construction
						19	11	8

Table 24 Confirmed indicators Cigrah

Panaderia Jerusalen

Even though this project has high cost overruns, relatively few indicators have been confirmed, 15 in total, see Table 25.

Frequency						Total		
3	DC9					1		
2	DC12	CE-S28	CC-C36	CC-C38	CO-E43	5		
1	DE1	DE2	DC8	DC11	DC13			
	DC14	DC15	CC-C39	CO-E42		9	Design	Construction
						15	9	6

Table 25 Confirmed indicators Panaderia Jerusalen

Appendix XI: Confirmed indicators summarized

In Table 26 an overview of all the confirmed indicators for all projects is given. A "1" means the indicator was confirmed to indicate rework and the last column shows the frequency of the indicator being confirmed. For example indicator DE1 has been confirmed for four projects. Figure 5 presents the same information more clearly in a bar chart. From this chart we can for example conclude that five indicators have been confirmed in all five projects and that this is 11% of all the indicators. Or that 35% of the indicators have been confirmed in more than two projects (and thus in more than half of the analyzed projects). This information has also been processed in the initial model, this presents a clear overview of the most occurring rework indicators, see Table 11.

Code	Lafise	Cerveceria	Aimar	Cigrah	Panaderia	Frequency
Lack of co-ordination	1	1		1	1	4
Unsuitable design	1				1	2
Design is hard to construct				1		1
Faulty design	1			1		2
Incomplete drawings	1			1		2
Erroneous drawings	1			1		2
Not enough time to design				1		1
A design change is initiated by the contractor	1	1	1	1	1	5
A design change is initiated by the end user/occupier	1	1	1	1	1	5
A design change is initiated by a supplier			1	1		2
A design change is initiated by Grupo Williams	1				1	2
A design change is initiated due to financial changes	1		1	1	1	4
A design change is initiated due to economic changes	1		1	1	1	4
A design change is initiated due to social changes					1	1
A design change is initiated due to legal changes					1	1
Communication problems	1					1
Interpretation problems	1					1
Omission errors by construction personnel	1		1			2
Mistakes in executing rules	1	1	1			3
Noncompliance of rule	1	1	1			3
Slips/lapses of attention	1	1	1			3
Erroneous workmanship		1				1
Faulty material handling						0
Faulty machine handling						0
Insufficient cleaning						0
Damage caused by GW or a subcontractor	1	1		1		3
Inexperienced personnel		1				1
Late deliveries of materials	1		1	1	1	4
Faulty manufacturing of materials						0
Material hard to work with						0
Delivery with wrong type of materials						0

Mistakes in planning						0
Faulty work preparation						0
Faults in materials administration						0
Wrong setting up						0
Changes in clients' wishes	1	1	1	1	1	5
Bad choice of material/method by client						0
Extra orders by client	1	1	1	1	1	5
Wrong information given by client		1			1	2
A change in construction methods in order to improve constructability	1	1	1	1		4
A change in construction methods due to site conditions	1	1	1	1		4
Machine not working satisfactorily		1	1	1	1	4
Machine breakdown or defects	1	1	1	1	1	5
Damage due to weather conditions						0
Damage due to natural disasters						0

Table 26 Overview confirmed indicators and their frequencies

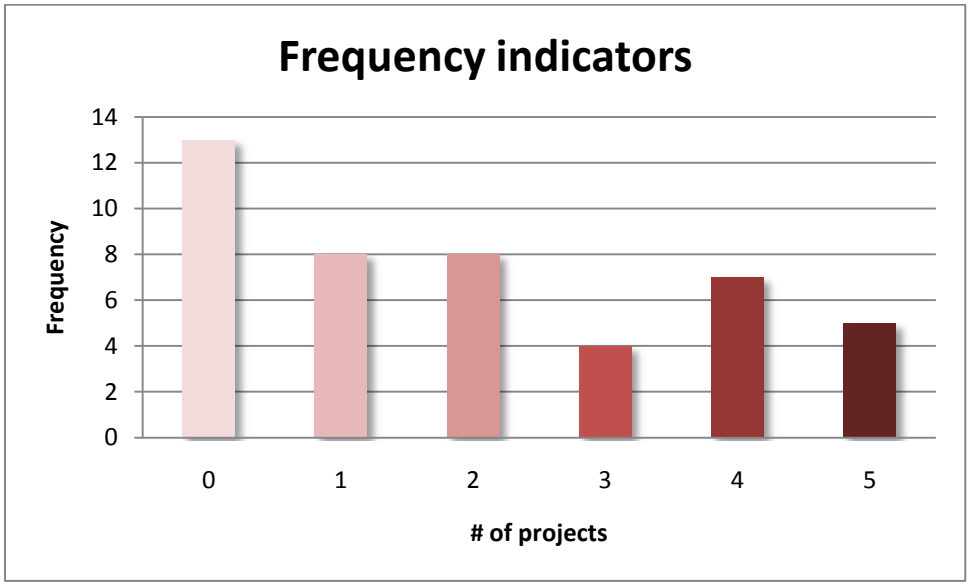

Figure 5 Bar chart frequency indicators

Appendix XII: Reliability analysis

Reliability has been tested for the survey data. Internal consistency has been measured by applying alternate form reliability. Inter-observer reliability has been measured by analyzing discrepancies between the answers of different interviewees and by comparing the ratios of confirmed indicators per function. For example a discrepancy was found when one person stated he agreed with an assertion while another person stated he disagreed with the same assertion.

Ratios of confirmed indicators

The first analysis compares the ratios of confirmed indicators. Ratios are used because not every interviewee was able to answer all the questions because of their function. The ratio shows the percentage of the answered questions that was answered in such a way that a rework indication was found. So if the ratio is 20%, one out of five indicators was confirmed for the specific project. The ratios have been plotted against the cost overrun of the projects. By doing so, it can also be analyzed if projects with higher cost overruns have more confirmed indicators. In the plots also a trend line has been added. Figure 6 to Figure 10 show the total ratios, the ratios per function and the ratios per function compared.

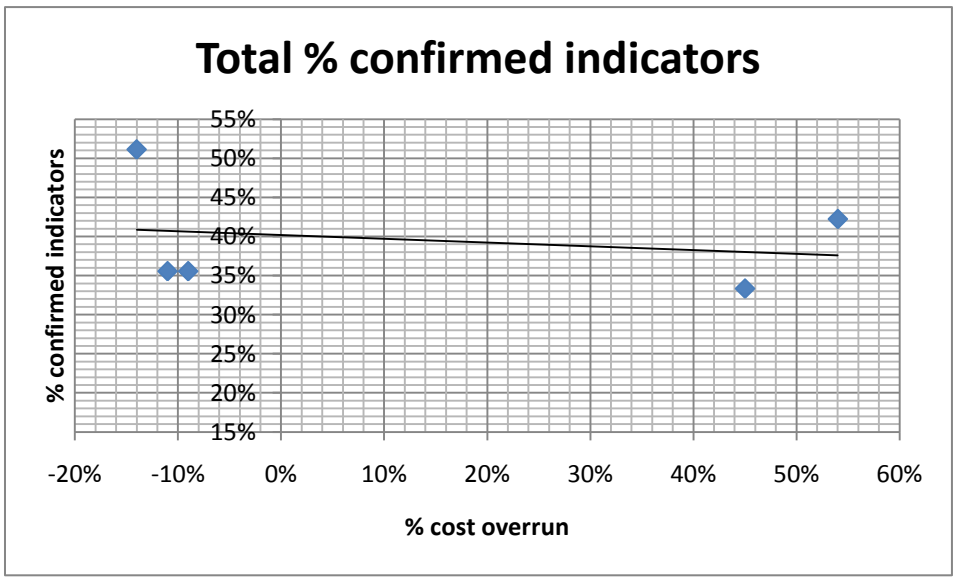

Figure 6 Total confirmed indicators

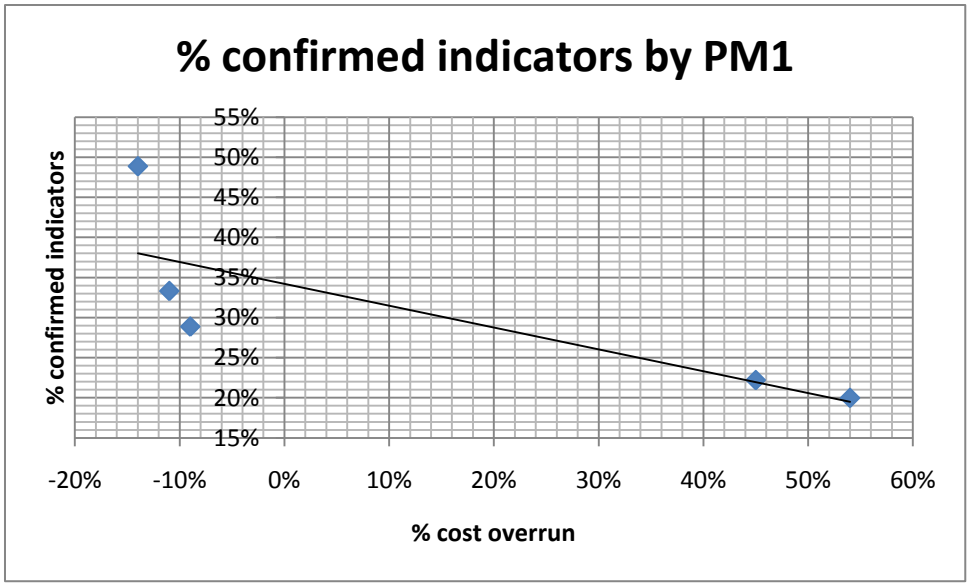

Figure 7 Confirmed indicators project manager 1

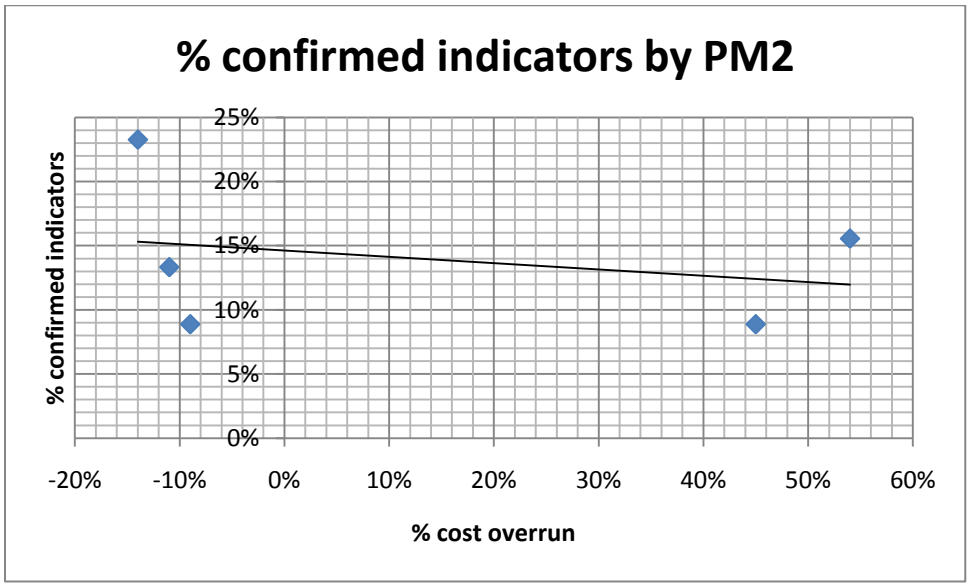

Figure 8 Confirmed indicators project manager 2

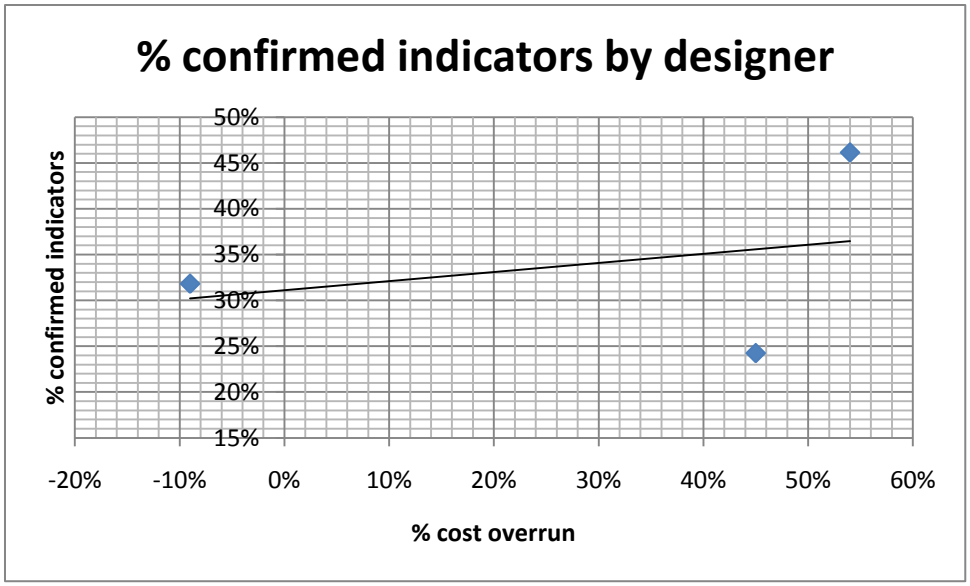

Figure 9 Confirmed indicators designer

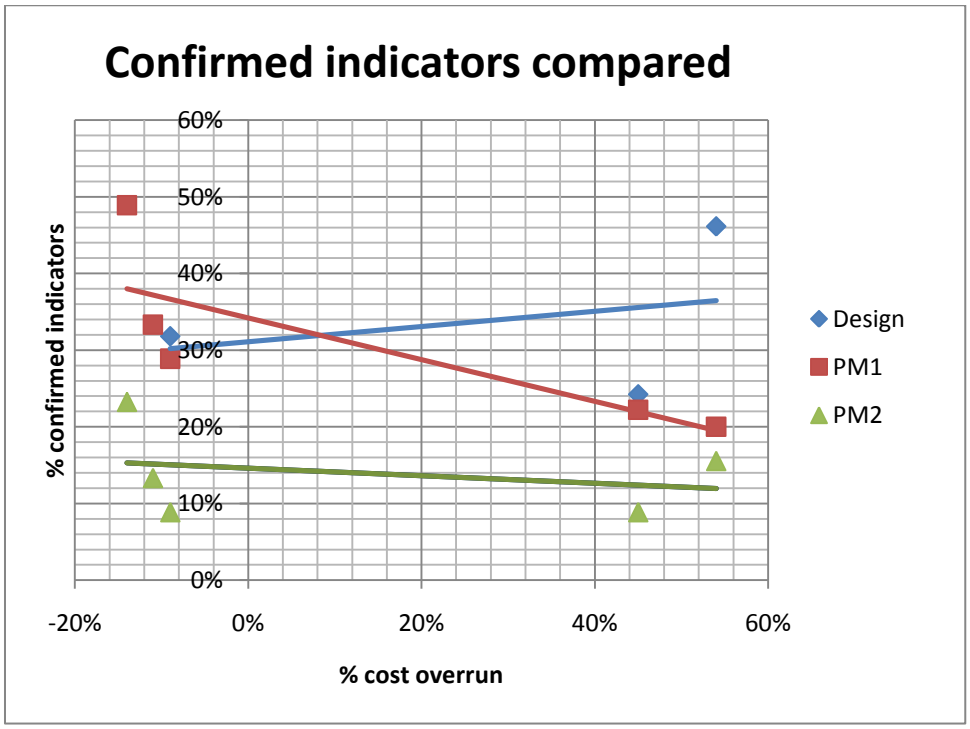

Figure 10 Confirmed indicators compared

Discrepancies

The analysis described above does not say much about the inter-observer reliability, this paragraph describes the method used that does analyze inter-observer reliability. Since the items all measure the same thing, they should be correlated with one another (Cronbach, 1951). If the answers are not the same, a discrepancy is found. For example one person states he agrees with an assertion while the other interviewees state they disagree even though the assertion tests the same cause for its occurrence. These discrepancies can have many origins, such as lack of communication, people forget about things or unwillingness to answer honestly. If there are more discrepancies reliability declines. A frequently used coefficient to analyze internal consistency, is Cronbach's alpha. The higher the coefficient the more consistency there is, and thus the reliability increases as well.

To calculate Cronbach's alpha the following formulas are necessary:

$$\alpha = \frac{N}{N-1}\left(1 - \frac{\sum_{i=1}^{N} S_{Y_i}^2}{S_X^2}\right),$$

in which

$$S_{Y_i}^2 = \frac{1}{m-1}\sum_{k=1}^{m}(Y_{ik} - Y_{i\cdot})^2,$$

$$Y_{i\cdot} = \frac{1}{m}\sum_{k=1}^{m} Y_{ik}$$

and

$$S_X^2 = \frac{1}{m-1}\sum_{k=1}^{m}(X_k - \bar{X})^2,$$

$$X_k = \sum_{i=1}^{N} Y_{ik}$$

$N = amount\ of\ items$
$Y_{ik} = score\ of\ person\ k\ on\ item\ i$
$m = amount\ of\ persons$
$S^2 = sample\ variances$
$Y_i = average\ score\ of\ on\ item\ i$
$X_k = test\ score\ of\ person\ k$

The calculations have been performed in Excel but when for some projects the alpha coefficient could not be calculated, computer software that can automatically calculate the coefficient was downloaded to verify the correctness of the calculations in Excel. The same values for Cronbach's alpha were found using SPSS. For la cerveceria Cronbach's alpha could not be calculated because the standard deviation was 0. The outcomes are presented in Table 12 in paragraph 7.2.

Alternate form reliability

The alternate form reliability tests internal consistency. By presenting the same assertions twice but differently formulated in one interview, the consistency of the interviewees answers can be analyzed. If the answers lead to the same scoring regarding rework indications, the answers are consistent and thus reliability increases. However when discrepancies occur reliability declines. Cronbach's alpha could not be used for this analysis, for many data sets errors were received when trying to calculate alpha. Therefore the reliability coefficient was differently defined. When calculating the alternate form reliability the gravity of the discrepancy has been taken into account. When the first answer was for example "agree" and the second "strongly agree" the discrepancy is accounted for as 0,5 while discrepancies of "more than one answer possibility" have been accounted for as 1.

In Table 27 an example of the alternate form reliability analysis is presented. A total of six indicators have been questioned twice and their answers are compared by calculating the absolute difference and then the discrepancy as explained above. The reliability coefficient is calculated as follows:

$$Reliability\ coefficient\ = \frac{(6 - \sum discrepancies)}{6} \times 100\%$$

This coefficient gives an idea about the amount of correspondence between the answers. A value of 70% or higher is seen as acceptable.

Project Manager 1

	Answer 1	Answer 2	Abs. Dif.	Discr.
DE3	-0,5	-1	0,5	0,5
DE4	-0,5	-0,5	0	0
CE-E18	-0,5	-0,5	0	0
CE-E19	-0,5	-1	0,5	0,5
CE-E22	-0,5	-1	0,5	0,5
CC-C36	1	1	0	0
Reliability coefficient		75%		

Project Manager 2

	Answer 1	Answer 2	Abs. Dif.	Discr.
DE3	-0,5	-0,5	0	0
DE4	-0,5	-0,5	0	0
CE-E18	-0,5	-0,5	0	0
CE-E19	-0,5	-0,5	0	0
CE-E22	-0,5	-0,5	0	0
CC-C36	0,5	0,5	0	0
Reliability coefficient		100%		

Designer

	Answer 1	Answer 2	Abs. Dif.	Discr.
DE3	-0,5	-0,5	0	0
DE4	-0,5	-0,5	0	0
CE-E18	0	0	0	0
CE-E19	0	0	0	0
CE-E22	0	0	0	0
CC-C36	-0,5	-1	0,5	0,5
Reliability coefficient		92%		

-1	No rework indication at all
-0,5	No rework indication
0	Undecided
0,5	Rework indication
1	Strong rework indication
0	Do not know

Table 27 Example Alternate form reliability analysis

Appendix XIII: Coordination activities

A list of most important coordination activities, adopted from Jha & Iyer (2005).

ID No.	Description of coordination activities
C_1	Implementing all contractual commitments
C_2	Arranging timely carrying out of all tests for inspections and approval by the engineer and maintaining records of the same
C_3	Arranging submission of samples of materials for approval by the engineer
C_4	Application of good technical practices
C_5	Preparation of a project quality plan in line with contract specification
C_6	Arranging remedial work methods and programs for executing in case of defect or damage
C_7	Identification of appropriate human resources, materials and equipments for the project
C_8	Estimation of the optimum resource requirements
C_9	Proper assignment of task to the available human resources for the project
C_{10}	Organization of resources (manpower, plant, and material) for effective utilization
C_{11}	Ensuring discipline amongst all employees
C_{12}	Resolving differences/conflicts/confusion among participants
C_{13}	Motivations of project participants
C_{14}	Development of a team spirit and receiving constructive input from all participants in the project
C_{15}	Identification of activities on critical path
C_{16}	Regular monitoring of critical path activities for adhering to schedule
C_{17}	Arrangement of required inputs like drawings, specifications, and technical details on time for execution
C_{18}	Agreement on detailed methods of construction with all the parties involved
C_{19}	Analysis of the project performances on time, cost and quality, detecting variances
C_{20}	Monitoring the overall functioning of each section and department of the project

Table 28 Most important coordination activities adopted from Jha & Iyer (2005)

Appendix XIV: Paper form & Microsoft Access database

In this appendix the rework report form and access database are presented and explained.

Rework report form

Figure 11 shows the standard rework report form. This form should be filled in every time a rework event is identified. This does not just apply to construction, every phase of the project might incur rework and should thus be reviewed. The responsible engineer at the construction site should report rework events during the construction and exploitation phase. The designer should do the same during the design phase. For the preparation phase it is more difficult to assign one person to this task because many different activities are undertaken, nevertheless should rework events be reported.

The report form speaks for itself and does not require a lot of explanation. It should be filled in as soon as possible after the identification of the necessary rework. It should then be passed on to the person responsible for the digital database of rework events. An explanation of the terms is given in the explanation of the digital database, see below.

Digital database

After the rework has been reported by filling in the rework report form it should be gathered in a digital database. Microsoft Access is a useful program to set up databases and a standard set-up for GW has been made. Processing the reported rework should be done by one person to make sure that *all* events per project are reported in *one* database. The digital database makes sharing the information easier and provides a more clear view of the situation. The database has been set-up in such a way that the database and reporting the rework events can be standardized and are thus more or less similar for all projects/rework events. Figure 12 and Figure 13 show two impressions of the Microsoft Access database, the events are imaginary. Figure 14 shows the form that can be used to process the paper forms into Microsoft Access. Figure 15 shows an overview report of the digital database that has been created by Microsoft Access. It is impossible to depict the whole set-up of the database. Below the use of the database will be explained. Since the people that will be processing the rework events might not speak English the explanation has also been translated in Spanish, see after the presentation of the figures below.

The use of Microsoft Access

Let me start by putting that this is the first time I have worked with Microsoft Access. There are probably many more functions that could be useful for processing the events in the database or making a report from the database to be discussed in evaluations. In the time available I have only explored the most basic functions of Microsoft Access to make the database set-up.

The set-up contains three sub-files:

Rework database: Table (Figure 12 & Figure 13)

This is the basis for the database. The table shows all the events that have been processed and their characteristics. Microsoft Access uses different "views" of the database, each with its own functions. The two most important ones while working in the table are the *datasheet view* in which rework

events can be processed in the database and the *design view* in which the set-up and characteristics of the database can be adjusted. The last might sometimes be necessary, for example the subcontractors will not be same for every project and this list should thus be adjusted at the start of the project. Processing the events into the database is better done through the rework forms, this will be explained further on.

Now all characteristics that can be found in the table will be shortly mentioned and explained. In the database the characteristics have been grouped. First general information is entered, then the cause is explained and categorized, then the consequences described and last an indication about the importance and status are given.

Characteristic	Description
#	The number of the rework event, will auto-number new events.
Date	The date the event has initially been reported. Select the date from the calendar that pops up.
Event description	Give a short description of the rework event.
Subcontractor	Which subcontractor was involved in the rework event (even if it was not the fault of a subcontractor)? As mentioned above, subcontractors differ per project, and since the example database is just imaginary, the list of contractors should be reviewed and adjusted every project.
Project phase	Which phase or activity did the rework event influence? Choose from preparation, design, construction and operation. These phases have been identified as the main phases for GW.
Cause	Describe the cause of the rework event
Type of rework cause	Define the type of rework cause; error, change, omission or damage.
Time delay	What was the effect of the rework event on time? What was the time delay due to the rework event?
Cost estimation	How much extra costs were made due to the rework event?
Priority	How important is quick resolution of the problem to be able to continue other activities; high, medium or low?
Status	What is the current status of the event? Closed means the event has been completely dealt with. Resolved means the problem itself has been solved but some things still have to be taken care of. Active means the problem has not been solved yet or is being solved right now.

Table 29 Description of characteristics of rework events in Microsoft Access database

The use of dropdown boxes to provide the answer possibilities has been applied for terms where standardized answers could be used. The use of these dropdown boxes makes processing the paper forms easier and less time consuming. Also are the databases standardized which makes evaluating them easier as well. As mentioned above might it sometimes be necessary to adjust the answering options in these dropdown boxes. These are the steps necessary to do so (also see Figure 16):

1. Open the rework database table
2. Switch to design view
3. Select the field you want to change
4. Go to the Lookup tab

5. Change the answering options in the field Row source (note that Display Control should be set to Combo Box, Row Source Type to Value List and Allow Value List Edits to Yes)
6. Switch back to datasheet view

Rework database: Form (Figure 14)

This form makes processing the paper forms a lot easier. This form is much more compact and clear than the table. Adding or editing the forms will automatically edit the table as well. Every rework event has its own form. So also if you just want information on one event, switch to this form. You can cycle through all the events by clicking "next record", this has been circled in Figure 14.

Rework database: Report (Figure 15)

In the report all rework events are published. It also calculates the total amount of reported rework costs for the project. Microsoft Access can also group or select particular events to present in the report. This can be very useful to gain more insight into the events. For example grouping the events by contractors involved insight can be gained into the performance of the contractors. To change the set-up of the report just start the report wizard under the create tab. Microsoft Access can also export the report to PDF format.

Formulario trabajo re-hecho

Información general

Proyecto: Fecha:

Reportado por:

Fase del proyecto

Preparación ☐ Diseño ☐ Construcción ☐ Explotación ☐

Descripción del evento

Descripción de la causa	*Tipo de causa del trabajo re-hecho*
	Error ☐ Omisión ☐ Cambio ☐ Daño ☐

Consecuencias	*Subcontratista(s) involucrado*	*Prioridad*
Tiempo de retardo: Total costos adicionales:		Baja ☐ Media ☐ Alta ☐

Procesamiento en base de datos *(Esto tiene que ser rellenado por el responsable de la base de datos digital!)*

Fecha de procesamiento:

Procesados por:

Figure 11 Rework report form (in Spanish)

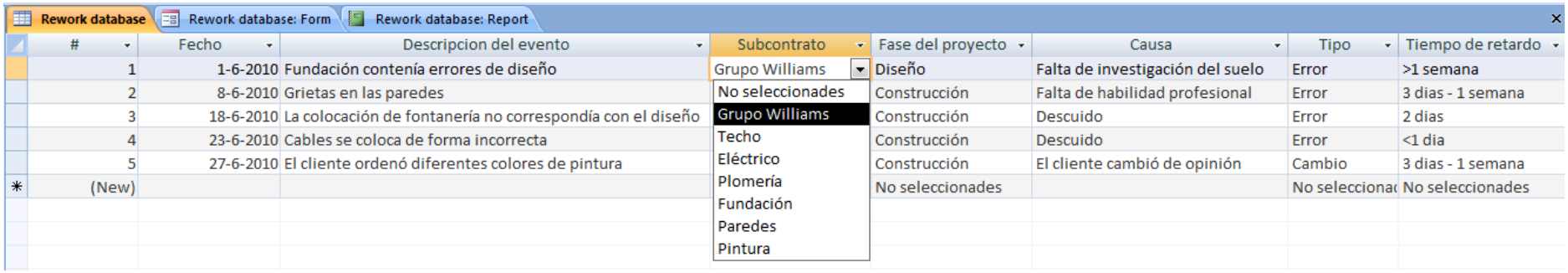

Figure 12 Impression of Microsoft Access database 1

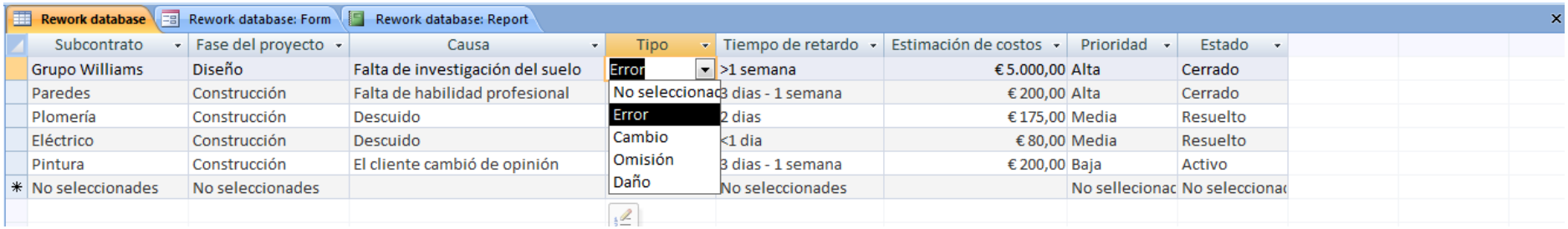

Figure 13 Impression of Microsoft Access database 2

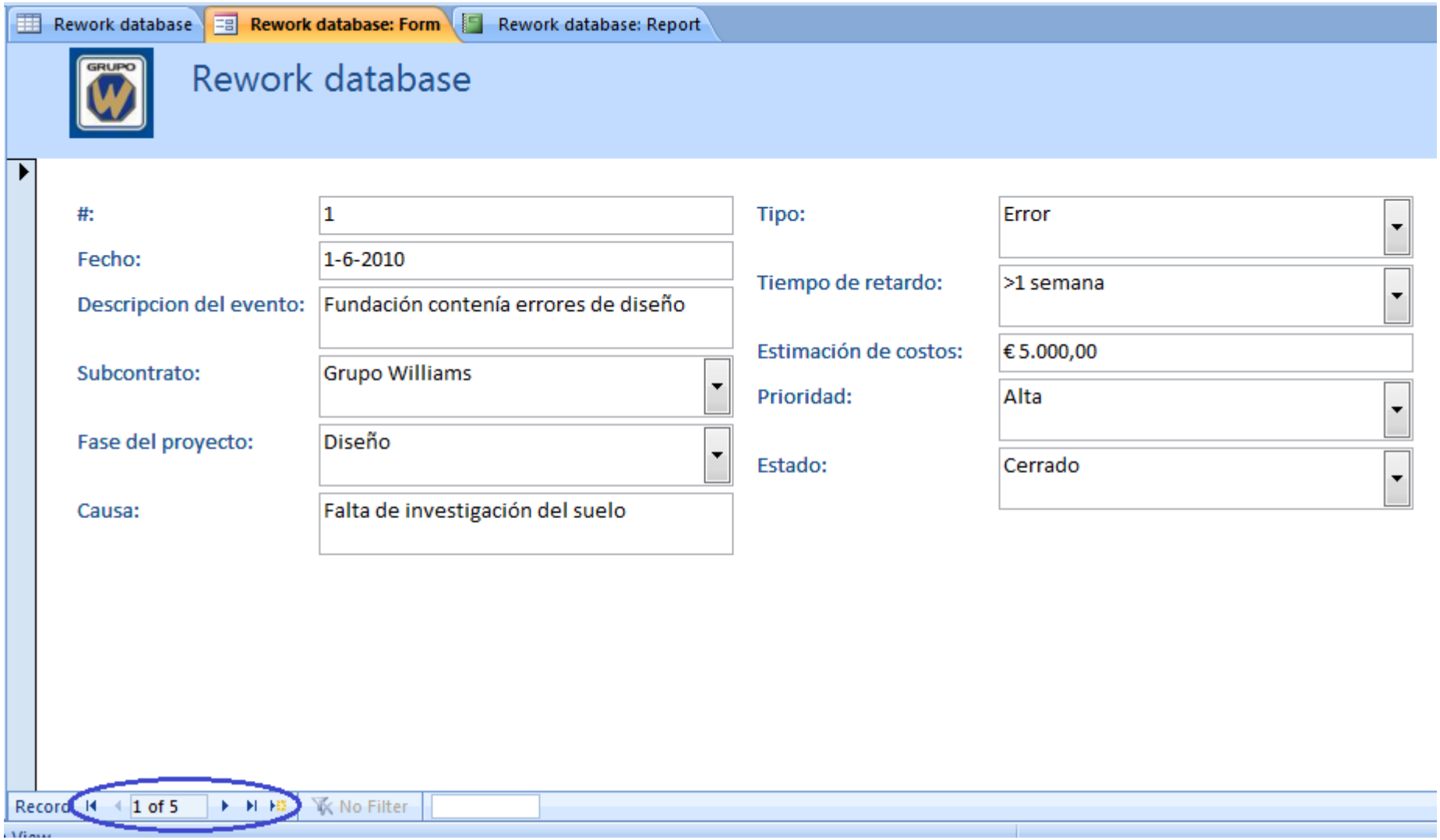

Figure 14 Rework database: Form

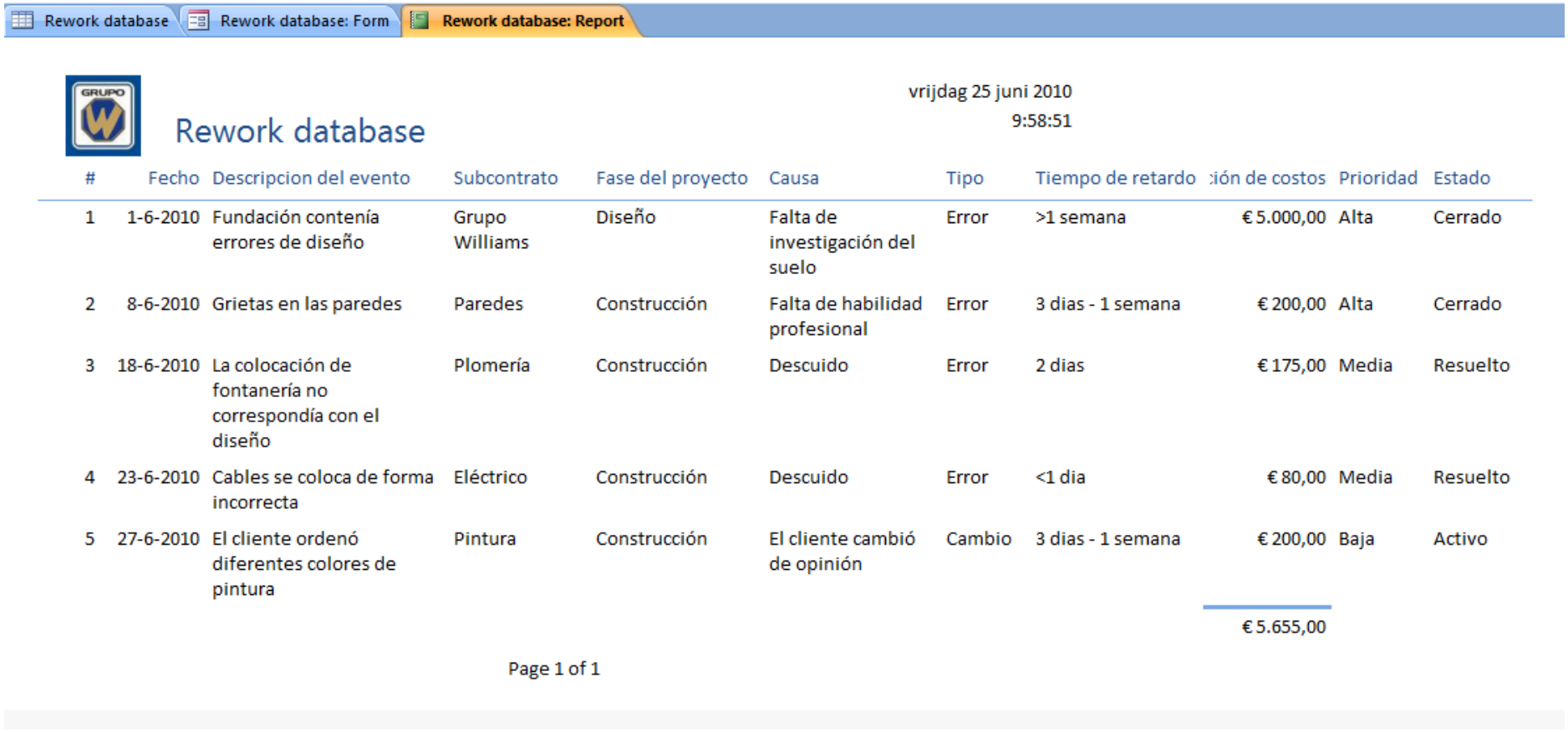

Figure 15 Rework database: Report

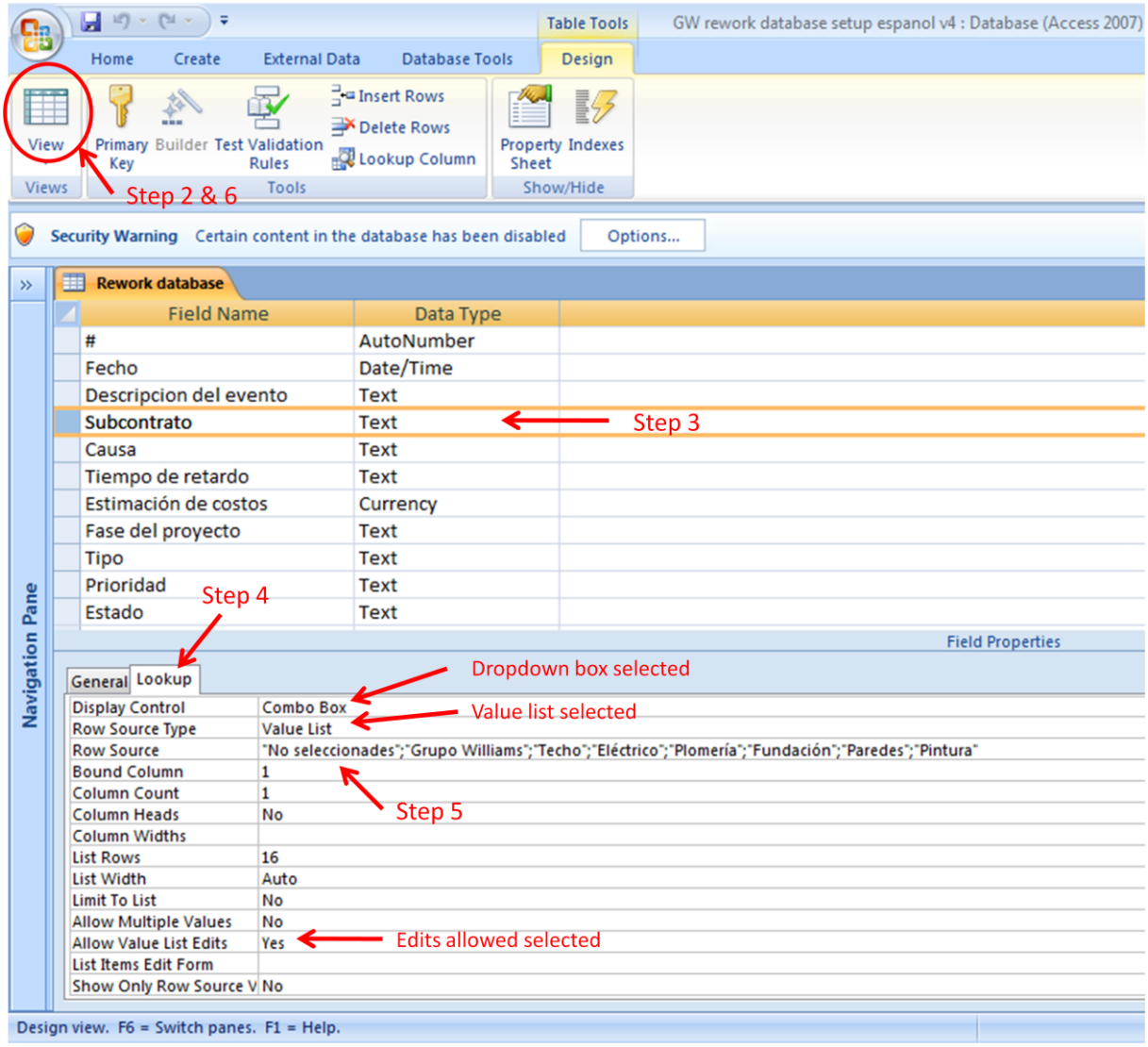

Figure 16 Editing dropdown boxes in Microsoft Access

Explicación: El uso de Microsoft Access

El base de datos contiene tres sub-expedientes:

Rework database: Table (Figure 12 & Figure 13)

Este es la base de la base de datos. La tabla muestra todos los eventos y sus características que han sido procesados. Microsoft Access utiliza diferentes "vistas" de la base de datos, cada uno con sus propias funciones. Los dos más importantes (en la tabla) son *la vista de hoja* (en que los eventos pueden ser procesados en la base de datos) y *la vista de diseño* (en que la puesta a punto y las características de la base de datos se puede ajustar). El último a veces puede ser necesario, por ejemplo los subcontratistas no será el mismo para cada proyecto y por eso la lista se debe ajustar al inicio del proyecto. Procesar los eventos en las base de datos es más fácil si usa la forma que está explicado más adelante.

En el siguiente cuadro explico todas las características que se puede encontrar en la base de datos

Característica	Descripción
#	El número del evento, el programa se numera nuevos eventos automáticamente
Fecho	El fecho en que el evento ha sido reportado inicialmente. Seleccione la fecha en el calendario que aparece.
Descripción del evento	Da una breve descripción del evento
Subcontratista	¿Qué subcontratista estuvo involucrado en el evento de trabajo re-hecho (aunque no fue por culpa de este subcontratista)? Como se mencionó anteriormente, los subcontratistas difieren por proyecto, y porque el ejemplo de la base de datos sólo es imaginaria, la lista de los contratistas debe ser revisados y ajustados cada proyecto.
Fase del proyecto	¿Qué fase o actividad estaba influenciado? Elija entre la preparación, diseño, construcción y explotación.
Causa	Describe la causa del evento de trabajo re-hecho
Tipo de causa	Se define el tipo de causa; error, cambio, omisión o daño
Tiempo de retardo	¿Qué fue el efecto del trabajo re-hecho en el tiempo necesario para terminar el proyecto? ¿Qué fue el tiempo de retraso debido al evento de trabajo re-hecho?
Estimación de costos	¿Cuántos costos adicionales se realizaron debido al evento de trabajo re-hecho?
Prioridad	¿Qué es la importancia de una resolución rápida del problema para la continuación de otras actividades; alta, media o baja?
Estado	¿Qué es la situación actual del evento? Cerrado significa que el evento está terminado completamente. Resuelto significa que el problema se ha resuelto pero hay cosas que todavía tienen que ser atendidos. Activo significa que el problema no ha sido resuelto todavía o se está resolviendo en este momento.

Table 30 Descripción de características de los eventos de trabajo re-hecho en la base de datos

El uso de listas desplegables para presentar las repuestas ha sido aplicado lo más frecuentemente posible. Por estas listas desplegables procesar los eventos en la base de datos es más fácil y necesita menos tiempo. También son las bases de datos estandarizados por estas listas y por eso la

evaluación de los proyectos es más fácil. Como se mencionó anteriormente, a veces podría ser necesario ajustar las opciones de respuesta en estas listas desplegables. Estos son los pasos necesarios para hacerlo (también puede ver eso en Figure 16, los conceptos se citan en Inglés):

1. Abra la tabla de base de datos
2. Cambie a "design view"
3. Seleccione la trama que desea cambiar
4. Va a la ficha "Lookup"
5. Cambie las opciones de repuestas en la trama "Row source" (tenga en cuenta que "Display Control" se debería establecer en "Combo Box", "Row Source Type" en "Value List" y "Allow Value List Edits" en "Yes")
6. Cambie a "datasheet view"

Rework database: Form (Figure 14)

Por esta forma procesar los eventos en la base de datos es más fácil. Esta forma es mucho más compacta y clara que la tabla. Añadir o editar las formas automáticamente edita la tabla tambien. Cada evento tiene su propia forma. Así también, si usted sólo quiere información sobre un evento, use esta forma. Si quiere navegar por todos los eventos, use "Next record" (puede verlo en Figure 14).

Rework database: Report (Figure 15)

En el reportaje se publican todos los eventos. También calcula el total de los costos de los eventos de trabjo re-hecho en el proyecto. Microsoft Access también puede ordenar eventos o seleccionar eventos en particular. Esto puede ser muy útil para obtener más información sobre los eventos. Por ejemplo ordenar los eventos por subcontratistas puede dar información del desempeño de los subcontratistas. Para cambiar la puesta a punto del reportaje, inicie "Report wizard" en la ficha "Create". Microsoft Access también puede exportar el reportaje a formato PDF.

Appendix XV: Rework monitoring checklist

The monitoring checklist form (see next page) presents statements which can be confirmed or denied. If they are confirmed, it indicates a rework event has happened, is happening or might happen in the near future. By filling in this checklist weekly, rework can be identified, communicated and resolved quickly. The main idea is that it functions as a reminder tool. Statements that are answered with "agree" are the ones that should be discussed at the next meeting. If one does not know the answer to a statement (for example because it is not in his/her field of expertise) check "don't know/not applicable". Since this checklist should be filled in weekly from the start of the project, it is also possible that some statements are not applicable yet or anymore because of the phase the project is in. For example statements about construction are not applicable in the first weeks of the project. In this case check "don't know/not applicable" as well. The checklist should be filled in by at least the designer and the engineer in charge at the construction site.

Proyecto: *Fecha:*

Reportado por:

Diseño - errores	Des-acuerdo	No sé/ No aplica	Acuerdo
Existe falta de coordinación, comunicación o interpretación en la elaboración del diseño	☐	☐	☐
El diseño es inadecuado para los propósitos del proyecto	☐	☐	☐
La constructibilidad del diseño es difícil	☐	☐	☐
El diseño contiene errores	☐	☐	☐
Los planos de diseño contienen errores/están incompletos	☐	☐	☐
El diseñador tiene tiempo insuficiente para completar el diseño	☐	☐	☐
Diseño - cambios			
Cambios de diseño son iniciados por el contratista	☐	☐	☐
Cambios de diseño son iniciados por el usuario final o ocupante	☐	☐	☐
Cambios de diseño son iniciados por otros involucrados	☐	☐	☐
Cambios de diseño son iniciados debido a cambios financieros	☐	☐	☐
Cambios de diseño son iniciados debido a cambios económicos	☐	☐	☐
Cambios de diseño son iniciados debido a otros cambios	☐	☐	☐
Construcción - errores			
Personal de construcción olvidó cosas o tareas	☐	☐	☐
Personal de construcción han cometido errores durante la construcción	☐	☐	☐
Reglas no seguidas, resbalones o lapsos de atención del personal causaron errores	☐	☐	☐
Falta de habilidad profesional causó errores	☐	☐	☐
Existe daño está causado por Grupo Williams o un subcontratista	☐	☐	☐
Materiales están siendos entregados demasiado tarde	☐	☐	☐
Existen otros problemas con materiales	☐	☐	☐
Existen problemas en el área de gestión del proyecto	☐	☐	☐
Construcción - cambios			
Cambios en los deseos del cliente tienen que ser procesados	☐	☐	☐
El cliente ha hecho órdenes adicionales	☐	☐	☐
Se realizo un cambio en los métodos de construcción	☐	☐	☐
Existen otras causas de cambios en la construcción	☐	☐	☐
Construcción - otros			
Existen problemas con la maquinaria	☐	☐	☐
Existen otras causas de daño (tiempo, desastres naturales, etc.)	☐	☐	☐

Figure 17 Rework monitoring checklist