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ΣΤΗ ΔΙΟΙΚΗΣΗ ΕΠΙΧΕΙΡΗΣΕΩΝ

Διπλωματική Εργασία

IMPLEMENTATION OF THE SIX SIGMA METHODOLOGY IN THE MAINTENANCE PROCESS OF CROWN HELLAS CAN

του

ΖΑΦΕΙΡΙΟΥ Ι. ΖΑΠΑΡΤΑ

Υποβλήθηκε ως απαιτούμενο για την απόκτηση του μεταπτυχιακού
διπλώματος ειδίκευσης στη Διοίκηση Επιχειρήσεων

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With a special feeling of gratitude to my loving parents and brother whose words for encouragement and push for tenacity ring in my ears. Also, to my wife and son who have never left my side and are very special.

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Abstract

The main objectives of our Thesis are to improve the efficiency of maintenance operations performed in the Thessaloniki plant of CROWN Hellas Can S.A. and to propose alternative strategies. At the same time, we want to reinforce the importance of implementing valid preventive maintenance policy by producing good reports with the assistance of a Computerised Maintenance Management System (CMMS).

To accomplish our goals, we apply the Six Sigma methodology which provides a structured approach to solving problems. The approach has five phases; Define, Measure, Analyse, Improve and Control (DMAIC). Our data had been collected during the high season and had been statistically processed by making use of appropriate statistical package such as Minitab. The business CMMS had been used to produce defect trees and to record both the defects and the corresponding breakdown times.

It had been proven that a high percentage of defects had been related to maintenance practices on different pieces of equipment. Also, the low utilization of the CMMS cannot support the production of good reports which could support the decision making on the best maintenance policy. Actually, this is the reason why the majority of most maintenance job is of corrective type.

Maintenance is a service function for the production department thus ensuring the smooth performance of the plant and the achievement of a competitive advantage over the competitors.

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1. Introduction

Six Sigma provides a structured approach to solving problems through the implementation of five phases; Define, Measure, Analyse, Improve and Control (DMAIC). The DMAIC methodology is simple, applicable to all environments and each phase has clear objectives, actions and outputs. Six Sigma focuses on the quality rather than the quantity of data on which it applies statistical techniques in a practical format.

Six Sigma could be the backbone of our organizational improvement and deliver better performance in both the utilization of resources and cost reduction efforts.

Optimum maintenance management is a necessity for every organization since present times enforce the opinion that maintenance should not be considered as a cost driving necessity, but as a way of enhancing the competitive advantage of a company.

Based on the fact that Hellas Can implements annual maintenance program of its equipment it is of interest to evaluate the effectiveness of this policy and if it focuses on the most critical equipment. Significant obstacles which had to be overcome are the absence of relevant data and the difficulty in distinguishing maintenance related breakdowns from those caused by other factors such as operator mistakes.

The present thesis is structured in five chapters with the second one focused on the literature of relevance in our research topic. The third chapter is a detailed description of the research methodology, while chapter four deals with the company background. The fifth chapter is the main part of our research since it is related with the implementation of DMAIC approach on the improvement of maintenance performance. Finally, we come up with the conclusions and findings.

2. Literature Review

2.1 The Six Sigma philosophy

The Greek alphabet letter σ is used for sigma to identify the variability of a process. A sigma quality level indicates how often defects are likely to occur and the higher sigma quality level is the lower the possibility that the process produces defects is. The Six Sigma objectives are to identify and eliminate non-conformances and defects in any service or product through the disciplined use of data, statistical analysis and process thinking. If implemented properly, the Six Sigma quality level is equal to 3.4 defects per million opportunities (DPMO) and can be shown as 3.4DPMO (the normality assumption of the process must hold a shift of up to $\pm 1.5\sigma$ for the mean of the process is allowed).

In simple words, the main Six Sigma objectives are:

- improve customer satisfaction;
- reduce costs;
- reduce cycle-time; and
- increase profit margins.

Six Sigma helps us to make process improvements by making use of the concept of Deming's plan-do-check-act cycle through the implementation of a five stage cycle of define-measure-Analyse-improve-control (DMAIC) (Pande et al., 2000; Andersson et al., 2006).

Mehrjerdi (2011) supports the opinion that: "its huge power lies in its "empirical", data-driven approach and the fact that it focuses on using quantitative measures of how the system is performing in achieving the goal of the process improvement and variation reduction". Six Sigma projects are based on the implementation of two methodologies, as listed below:

1. DMAIC: for existing products and processes, the DMAIC methodology applies. There are five steps to be considered for this case. The steps are define, measure, Analyse, improve and control. It is applied when the cause of the

problem is unknown or unclear, the potential of significant savings exists and the project can be done in 4-6 months (Breyfogle et al., 2001).

2. DMADV: for new products and processes, the DMADV methodology applies. The first three steps of DMADV are the same with those of DMAIC. For DMADV, the final two steps focus on designing and verifying the future product or process inputs (Mehrjerdi, 2011).

Each step has its corresponding tools and techniques in order to improve the process and sustain control of it. The following table (Table 1) illustrates the DMAIC steps to be taken, tools to be used and the deliverables.

Any practitioner of Six Sigma comes to the conclusion that Six Sigma is a philosophy as well as a scientific approach. McAdam and Lafferty (2004) are of the opinion that: "some way to go before it is fully accepted as a broad change philosophy". The same authors go on suggesting that Six Sigma provides important business metrics to an organization to accommodate the integration of total quality management (TQM) throughout the business unit.

This is the reason why Six Sigma walks hand by hand with Total Quality Management (TQM) and this is shown in the following equation (Anbari, 2002):

Six Sigma = TQM + Stronger customer focus

+ Additional data analysis tools + Financial results + Project management

DMAIC steps	Steps to be taken	Tools to be used	Deliverable
Define	Define customers and requirements (CTQs) Develop problem statement, goals and benefits Identify champion, process owner and team Define resources Evaluate key organizational support Develop project plan and milestones Develop high level process map	Project charter Process flowchart SIPOC diagram Stakeholder analysis DMAIC work breakdown structure CTQ definitions VOC	Fully trained team is formed, supported and committed to work on improvement project Customers identified and high impact Characteristics (CTQs) defined, team charter developed, business process mapped
Measure	Define defect, opportunity, unit and metrics Detailed process map of appropriate areas Develop data collection plan Validate the measurement system Collect the data Begin developing $Y = f(x)$ relationship Determine process capability and sigma baseline	Process flowchart Data-collection-plan/example Benchmarking Measurement-system analysis VOC Process sigma calculation	Key measures identified, data collection planned and executed, process variation displayed and communicated, performance base lined, sigma level calculated
Analyze	Define performance objectives Identify value/non-value-added process steps Identify sources of variation Determine root cause(s) Determine vital few x's, $Y = f(x)$ relationship	Histogram Pareto chart Time series/run chart Scatter plot Regression analysis Cause and effect diagram Whys Statistical analysis Non-normal data analysis	Data and process analysis, root cause analysis, quantifying the gap/opportunity
Improve	Perform design of experiments Develop potential solutions Define operating tolerances of potential system Assess failure modes of potential solutions Validate potential improvement by pilot studies Correct/re-evaluate potential solution	Brainstorming Mistake proofing Design of experiments Pugh matrix House of quality FMEA Simulation software	Generate (and test) possible solutions, select the best solutions, design implementation plan
Control	Define and validate monitoring and control system Develop standards and procedures Implement statistical process control Determine process capability Develop transfer plan, handoff to process owner Verify benefits, cost savings/avoidance, profit growth Close project, finalize documentation Communicate to business, celebrate	Process sigma calculation Control charts (variable and attribute) Cost savings calculation	Documented and implemented monitoring plan, standardized process, documented procedures, response plan established and deployed, transfer of ownership

Table 1: DMAIC steps, tools to be used and deliverables (Source: Mehrjerdi, 2011).

Apart from the traditional Six Sigma tools, random Monte Carlo simulation is a powerful tool which may be applicable to either the Analyse and improve stages of a DMAIC project or the Analyse and design stages of a DMADV project (Mehrjerdi, 2011).

There are also a number of disadvantages that must be addressed for Six Sigma to become a sustainable improvement technique. Firstly, the training for and solutions put forward by Six Sigma can be prohibitively expensive for many businesses (Senepati, 2004; Pepper and Spedding, 2009). Secondly, according to Senepati (2004) is of the opinion that the correct selection of improvement projects is critical. Thirdly, Antony (2004) discusses the non-standardization of training efforts (in terms of belt rankings, etc.), and how this accreditation system can easily evolve into a bureaucratic menace, where time and resources are misspent focusing on the number of "belts" within the organization, and not the performance issues at hand. Mika (2006) suggests that another drawback of Six Sigma is that it cannot be embraced by the "average worker on the floor". Finally, Pepper and Spedding (2009) claim that: "Six Sigma also faces a real danger of becoming lost in a consultancy practice, being oversold and incorrectly used, in a similar way to TQM".

Motorola, an early corporate adopter of the Six Sigma methodology, has made some changes to the Six Sigma methodology and introduced a new umbrella called new Six Sigma. According to Mehrjerdi (2011): “The new Six Sigma integrates key disciplines from finance, engineering, strategy, statistics, tangible and intangible asset management, IT and industrial organizational psychology. The focus of the new Six Sigma method is away from simply reducing defects and towards reducing variation around accomplishing business goals”. The following table (Table 2) illustrates the history of Six Sigma in short.

1920 :	The word 'sigma' became a unit to measure quality variation.
1985 :	Motorola used 'Six Sigma' as an informal name for an in-house initiative for reducing defects in production processes.
1989 :	Six Sigma became a formalised in-house 'branded' name for an improvement methodology.
1991 :	Motorola certified its first 'Black Belt'
1995 :	General Electric implements Six Sigma
2000 :	6Sigma has become a popular methodology used by many corporations for quality & process improvement.

Table 2: The history of Six Sigma (Source: CROWN Green Belt Training, 2011).

However, Six Sigma has brought large cost savings and benefits to very small companies as well. Besides, Basu (2001) and Basu and Wright (2003) suggest that organizations adapt a new wave of Six Sigma known as Fit Sigma. The Fit Sigma philosophy is the adaptation of the Six Sigma approach to “fit” an organization’s needs so as to maintain performance and organizational fitness.

2.2 The DMAIC methodology

Six Sigma provides a structured approach to solving problems. The approach has, as already been written, five phases or steps; Define, Measure, Analyse, Improve and Control (DMAIC). The DMAIC approach is generic and applicable to all environments. Different industries may use specific tools more than others, but the DMAIC phase always remains valid. The power of the DMAIC problem solving flow lies in its simplicity and clarity. Each phase has clear objectives, actions and outputs.

Some comments for each phase have been provided in Table 1, however, you may read additional details in the following paragraphs:

Define: The Define phase focuses only on the problem – root causes and solutions come later on. The Define Phase is about making sure that all the key stakeholders have a joint understanding of the problem to be solved, the SMART objectives (S: specific, M: measurable, A: achievable, R: relevant, T: time bound) to be delivered, and the full scope of the project - before moving forward into the detailed mapping and measurement of the process.

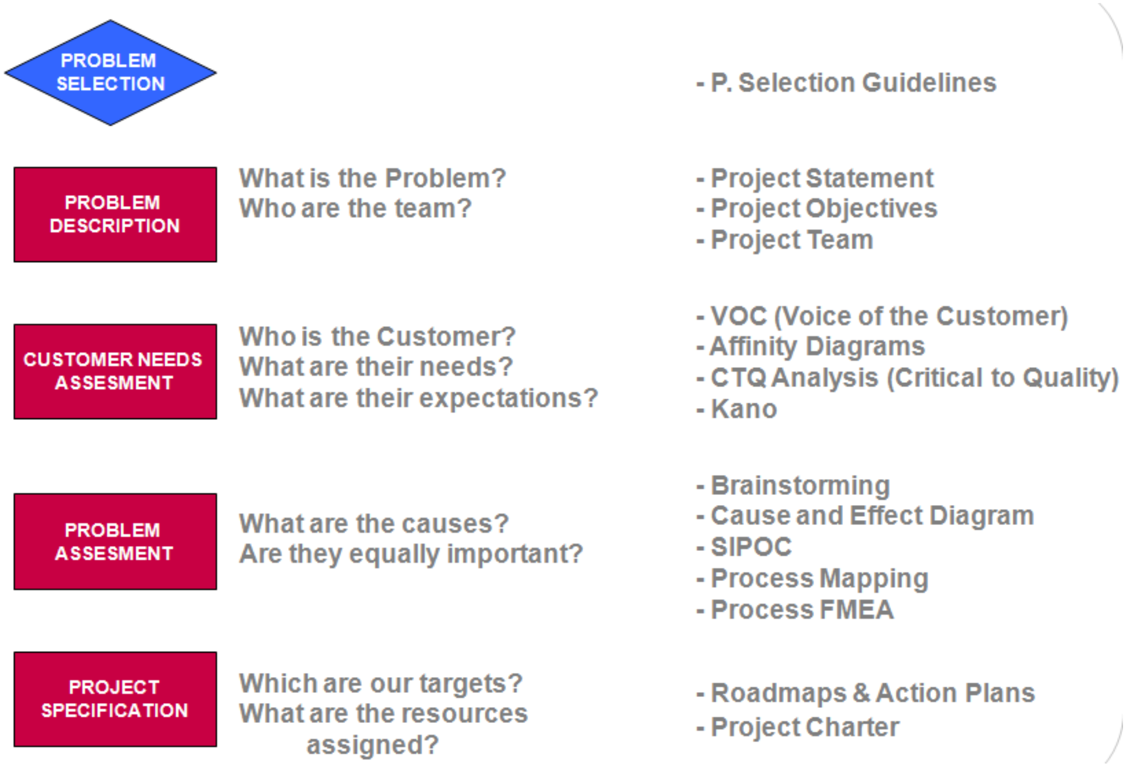


Figure 1: The Define phase (Source: CROWN Green Belt Training, 2011).

Measure: The Measure phase aims at setting a stake in the ground in terms of process performance (a baseline) through the development of clear and meaningful measurement systems. The Measure phase builds upon the existing data available (introducing new data collection and measurements, if necessary) in order to fully understand the historical `behavior´ of the process.

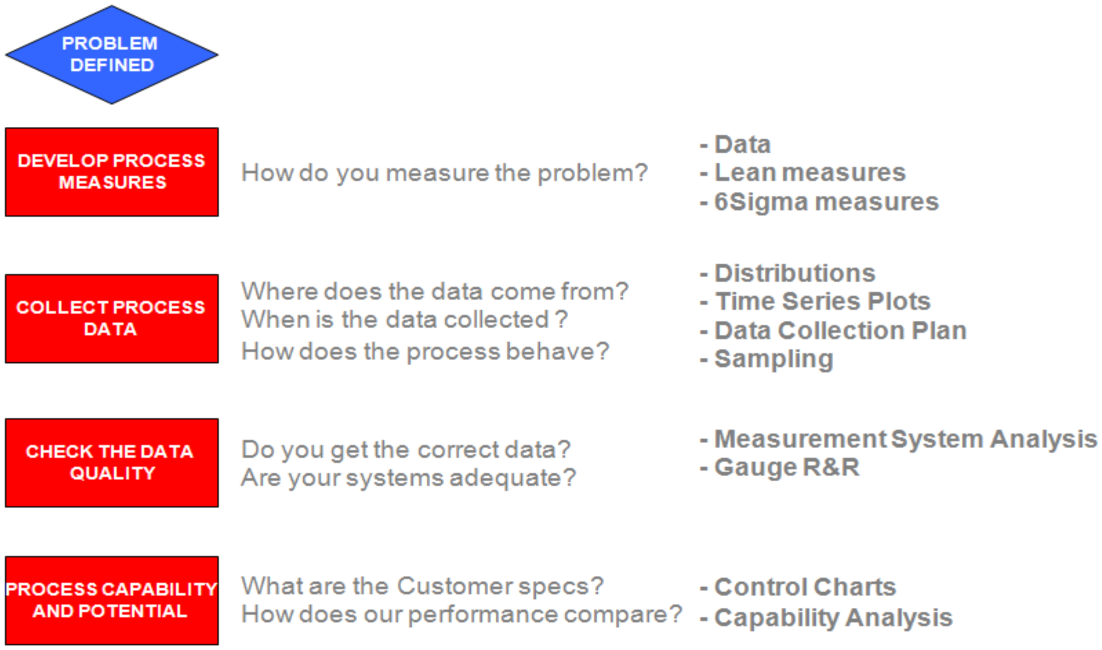


Figure 2: The Measure phase (Source: CROWN Green Belt Training, 2011).

Analyse: The goal of the Analyse phase is to understand how the process actually work, identify the root causes of the process variation and to confirm those causes using appropriate data analysis tools. The main issue is to clarify the hypothesis question that the analysis is going to answer.

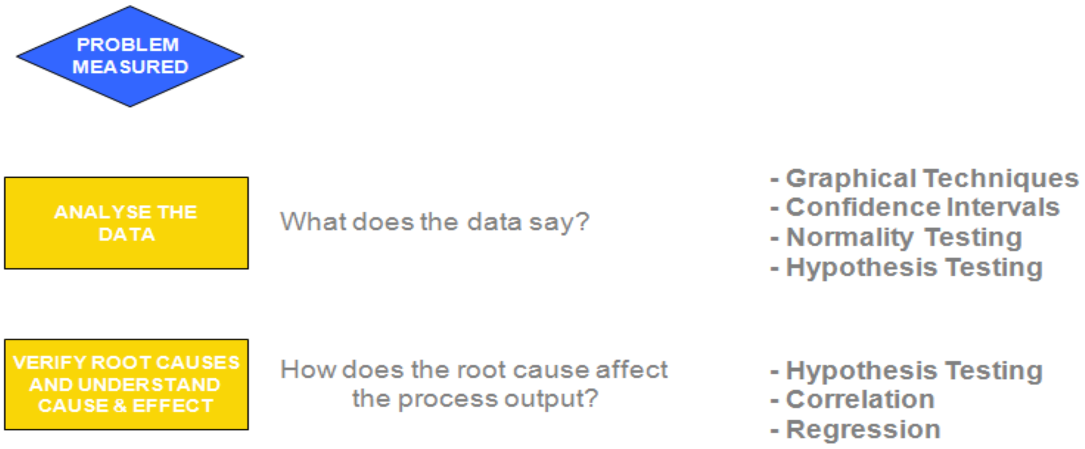


Figure 3: The Analyse phase (Source: CROWN Green Belt Training, 2011).

Improve: On the basis that you have a clear knowledge of the root causes of the problem, you need to implement different improvement solutions and evaluate how these address the problem identified during the previous phase. To accomplish this task, you have to check how the KPIs has developed during the Measure phase behaving. The best solution needs to be verified (pilot trial) for its effectiveness.

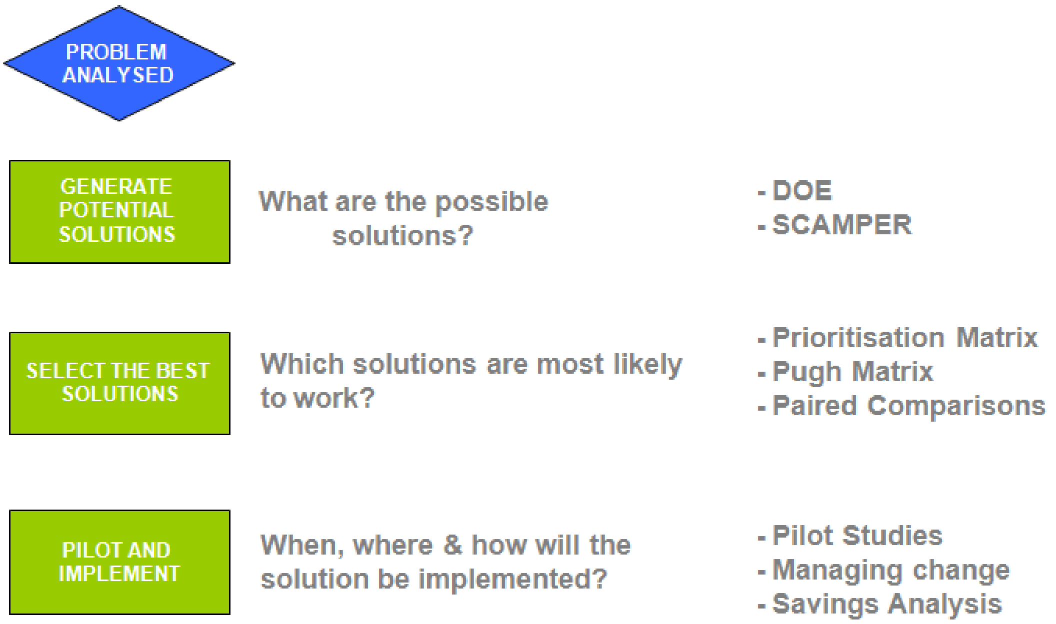


Figure 4: The Improve phase (Source: CROWN Green Belt Training, 2011).

<u>Control</u>: The control phase aims at ensuring that the improvements achieved will be sustained in the long term. For this reason, there must be an ongoing measurement system so that we are able to see the process continues to be both capable and stable. Certainly, we must make use of visual management to communicate the results of the project. Also, it would be useful to apply the lessons learnt from a specific project to different areas within an organization through appropriate knowledge management.

Figure 5: The Control phase (Source: CROWN Green Belt Training, 2011).

2.3 Need for maintenance performance improvement

It is generally accepted that maintenance spending constitutes a large part of the operating budget in firms with heavy investments in machinery and equipment. In order to identify the efficiency and effectiveness of the maintenance system we need to measure the system's performance (Parida and Kumar, 2006).

The goal for every organization is to achieve the optimum maintenance and cease considering maintenance as a cost driving necessity instead of a competitive resource, especially within the manufacturing industry. According to Kelly (2006) optimum maintenance is regarded as: "to achieve the agreed plant operating pattern, availability and product quality within the accepted plant condition (for longevity) and safety standards, and at minimum resource cost". If maintenance activities are focused on critical pieces of equipment and there is a well organized program of preventive maintenance then management will be able to discover the connections between maintenance activities and profitability. Wireman (1990) means that as much as one third of the maintenance cost is unnecessarily spent due to bad planning, overtime costs, bad use of preventive maintenance, etc. In similar meaning, Todinov (2006) states that such waste also leads to increased production costs. Failures in production systems may cause high losses, for instance in the form of lost production time or volume, negative impact on the environment, lost customers, warranty payments, etc.

From all the above mentioned it is quite clear that we needed to improve the quality of the maintenance process and to demonstrate these quality improvements in terms of financial benefits. To support these efforts both the concept of cost of poor quality (CoPQ) and the 6Sigma tools were introduced. Salonen and Deleryd (2011) express the opinion that: "the concept of poor maintenance (CoPM) can help leading the way for management to look upon maintenance activities as strategically important and vital to business continuity and prosperity and not just another cost-center costing them money.".

In order to evaluate the efficiency and effectiveness of the maintenance activities a variety of financial models have been proposed. The majority of them divide the maintenance costs into direct and indirect costs. Direct costs consist of labor costs, spare parts, and other costs that clearly are directly linked to maintenance activities. Indirect costs include the cost of recovering for lost production (due to equipment failures) cost of insufficient quality etc. In addition, a third category of maintenance costs, Non-realized revenue, refers to the income loss due to reduced sales volumes, missed delivery dates and such, caused by poor maintenance (Ahlmann, 2002). Another proposed model (Oke, 2005) evaluates maintenance profitability based on fixed prices per amount of service provided. Even though the model is formulated to deal with inflation rates, it still assumes that every service has the same price. Moreover, other approaches are the value-driven maintenance (VDM) which is based on the Present Value model, and a model which applies balanced scorecard concept (Liyanage and Kumar, 2003).

The concept of CoPM is applied on the process model which is used to assess the CoPQ (Schiffauerova and Thomson, 2006). Before we move on to the clarification of the process model we have to mention that Salonen and Deleryd (2011) express dependability as: “a collective term for reliability, maintainability and maintenance supportability, as defined by the Swedish Standards Institute (2001).” It is commonly known that maintenance is performed either for prevention or for correction of failures in production equipment. By making use of the process model on the maintenance process we take into consideration both costs of conformance, which guarantee dependability from the maintenance department and costs of non-conformance which do not contribute to the dependability.

Due to the fact that both preventive and corrective maintenance may relate to either costs of conformance or costs of non-conformance, the basic CoPM model makes reference to four categories of costs (see Figure 6):

(1) costs for indispensable corrective maintenance;

(2) costs for valid preventive maintenance;

(3) costs for non-accepted corrective maintenance; and

(4) costs for poor preventive maintenance.

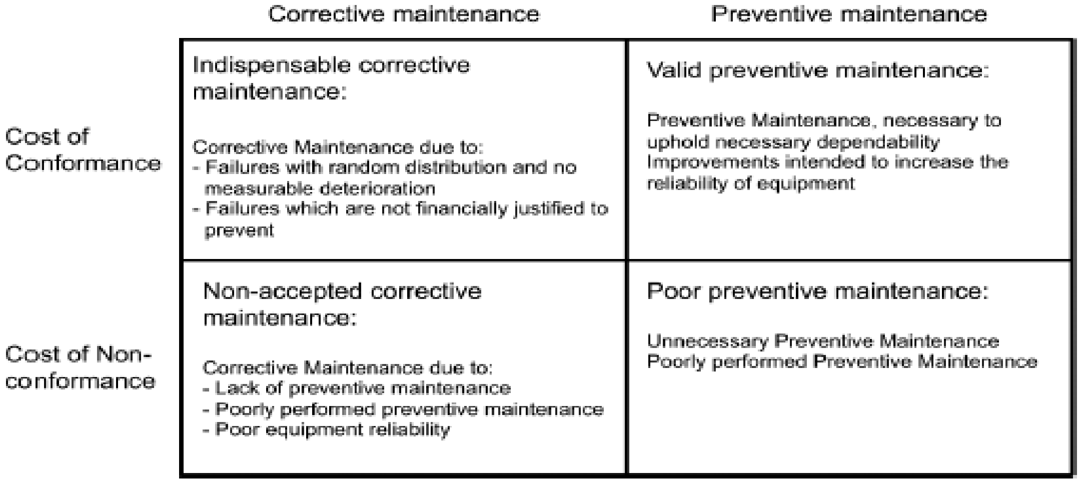


Figure 6: The expected outcome of structured use of the CoPM concept (Source: Salonen and Deleryd, 2011).

Furthermore, Salonen and Deleryd (2011) comment that: "by optimizing the actions and costs of conformance, we reduce the waste of non-conformance, and thereby the total cost", as illustrated in Figure 7.

2.4 Evaluation of maintenance strategies effectiveness

In order to avoid having maintenance being considered as just another cost centre we need to be able to demonstrate the relationship between maintenance activities and enhancement of the competitive advantage of a company. This is a common conclusion

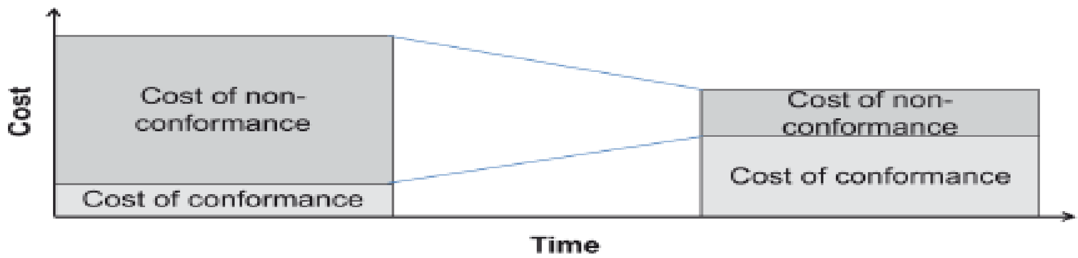


Figure 7: The proposed CoPM model (Source: Salonen and Deleryd, 2011).

among many maintenance managers who, however, neither have the knowledge nor the tools to evaluate the effectiveness of their maintenance strategy in achieving this objective (Pintelon, Pinjala and Vereecke, 2006). Based on the fact that, maintenance supports the overall business performance, its objectives are mainly derived from manufacturing and business strategies.

In this point we will provide a short description of the different kinds of business strategies and functions in an organization and how they collaborate in supporting the corporate strategy. Finally, we make reference to the various terms of maintenance strategies and their effectiveness.

By the term corporate strategy we mean the organization's overall direction and the management of its business units and it is considered to be the highest level of strategy formulation. Corporate strategy clarifies the general attitude of the organization towards its alternatives such as growth, stability or retrenchment, the assignment of resources and cash flows to the business units and the management of both the internal and external environment forces. In the medium level of strategy formulation, we have the business strategy, also called competitive strategy, which emphasizes in improving the competitive position of a corporation's products or units and is distinguished in cost leadership, differentiation, cost focus and focus differentiation. Functional strategy is formulated in the lowest level of a company and is related with the maximization of resources productivity within a specific department e.g. manufacturing, finance, maintenance, etc. Both Tsang (1998, 2002) and Kelly (1997) express the view that maintenance strategy is defined at functional hierarchy level similar to manufacturing or any other function.

In the literature, there have been a number of various definitions of the term "maintenance strategy" which has been expressed through the implementation of different maintenance policies like corrective or breakdown maintenance (CM), preventive maintenance (PM), predictive maintenance (PDM) and reliability-centered maintenance (RCM). Another one significant maintenance concept is the total productive maintenance (TPM) originated in Japan in 1971 as a method for improved machine availability through better utilization of maintenance and production resources. TPM is an extension of total quality management (TQM) and has basically 3 goals -

Zero Product Defects, Zero Equipment Unplanned Failures and Zero Accidents. However, most of the definitions ignore the dynamics of the maintenance function as a whole and this is the main reason the top management of a company often considers it as a part of manufacturing overheads.

The goal of having an effective maintenance strategy which fits the needs of the business is very difficult to be achieved. Another difficult task is how we intend to evaluate the performance of this strategy. To do so, we will consider the maintenance strategy as a function of four structural and six infrastructural elements based on Hayes and Wheelwright's decision elements of manufacturing strategy (Pinjala, Pintelon and Vereecke, 2006) , as illustrated in Figure 8.

Structural decision elements	
Maintenance capacity	Capacity in terms of work force, supervisory and management staff. Shift patterns of work force, temporary hiring of work force
Maintenance facilities	Tools, equipment, spares, workforce specialization (mechanics, electricians, etc.), location of workforce
Maintenance technology	Predictive maintenance, or condition monitoring technology, expert systems, maintenance technology (intelligent maintenance)
Vertical integration	In-house maintenance versus outsourcing and relationship with suppliers
Infrastructure decision elements	
Maintenance organization	Organization structure (centralized, decentralized, or mixed), responsibilities
Maintenance policy and concepts	Policies like corrective, preventive and predictive maintenance. Concepts like total productive maintenance (TPM), reliability centred maintenance (RCM)
Maintenance planning and control systems	Maintenance activity planning, scheduling. Control of spares, costs, etc. Computerized maintenance management systems (CMMS)
Human resources	Recruitment policies, training and development of workforce and staff. Culture and management style
Maintenance modifications	Maintenance modifications, equipment design improvements, new equipment installations and new machine design support
Maintenance performance measurement and reward systems	Performance recognition, reporting and reward systems, Overall equipment effectiveness (OEE) and balanced score card (BSC)

Figure 8: Summary of maintenance strategy decision elements (Source: Pintelon, Pinjala and Vereecke, 2006.

The structural decision elements are the resources of maintenance, the infrastructure decision elements determine the way of using these resources and the combination of both of them is the maintenance strategy being implemented.

In order to evaluate the effectiveness of the maintenance strategy we establish both consistency and contribution criteria. The consistency criteria involve two types, namely internal and external. The internal one expresses how consistent the maintenance function with other functions like manufacturing and human resources in the business unit is. On the other hand, external consistency is between the maintenance function and the environment of the business unit (for example governmental restraints on safety and the environment) (Pintelon, Pinjala and Vereecke, 2006).

We discussed earlier the fact that maintenance is regarded as nothing else but an additional cost centre. However, maintenance can contribute to the creation of competitive advantage by either modifying installed equipment or reducing the set-up times of machinery. Besides, a well-organized maintenance activity will allow a company to achieve satisfactory delivery times and competitive cost products through reduced breakdown time and cost (Swanson, 1997; Pintelon et al., 2000). In any case, we may use the consistency and contribution criteria to categorize a maintenance strategy into four different stages based on Hayes and Wheelwright's framework, as it is adjusted to evaluate the effectiveness of maintenance strategy.

According to Pintelon, Pinjala and Vereecke (2006), Stage 1 companies ("internally neutral") regard maintenance mainly as manufacturing overheads and do not realize its full potential. Since they do not have internal expertise they outsource majority of their maintenance activities and rely heavily on either original equipment manufacturers (OEM) or outside maintenance service providers in solving complex equipment problems.

Stage 2 companies pay attention to what the competitors (external environment) do in matters of maintenance and this is the reason they are either named as "externally neutral". Even though the majority of maintenance is carried out on a reactive basis, a reasonable amount of preventive maintenance is also done.

Stage 3 companies are considered to be "internally supportive" from the point of view of consistency, as they incorporate maintenance in the company's overall strategy, although maintenance potential is not fully exploited. Going back to the human resources factor of the infrastructure decision elements, we find out that maintenance crew and staff is better equipped with skills and training on a regular basis.

Furthermore, proactive maintenance policies like preventive and predictive maintenance are carried out and maintenance is better managed by planning and scheduling and through high use of CMMS (Computerized Maintenance Management Systems).

Finally, Stage 4 companies, also known as “externally supportive”, foresee maintenance process as a potential source of competitive advantage and involve maintenance in major capital investment decisions. Stage 4 companies pay great attention to the voice of the customer by listening to the wishes of the internal customers e.g. manufacturing. They strive to reduce the spare parts cost by producing their own manufacturing equipment and maintain high performance in plant safety and environmental issues.

3. Research methodology

Following the previous two chapters, we realize the importance of maintenance as a critical factor in the establishment of competitive advantage. For this reason, a case study regarding the optimization of maintenance performance was developed in CROWN Hellas Can S.A, Thessaloniki Plant.

Our thesis is a part of a wider project that is conducted in the company and is related to the implementation of world class performance (WCP) concepts to all our activities e.g. safety, production, maintenance etc. To gain a clearer understanding of the maintenance process a six month Six Sigma project will have been developed with completion date the 31st of January 2012.

A kick-off meeting took place in August in order to select a project which would fit the business needs. The participants were the plant manager, the can lines and engineering supervisor, the logistics supervisor and the CMMS coordinator. This limited management structure was considered to be critical for the monitoring of the project progress. After the collection and initial process of the data, another meeting took place on October, 13th to track the financial benefits accrued by this initiative and the result was the Project Charter form (Table 5).

Our research is of experimental type since we tried to discover cause – and – effect relationships between maintenance activities and various kinds of defects. We applied Six Sigma and, specifically, the methodology followed was the DMAIC in which each one of the five phases is a combination of both qualitative and quantitative techniques.

The study population is the total occurrence of defects and we set out objectives to attain through the implementation of improving actions based on the findings. It is the belief of the author that our thesis will add a scientific approach to the existing maintenance function in the plant.

As far as literature review is concerned, we focused our interest on journals and articles of relevance in our research topic. Regarding data, we established a primary data collection system through observations and individuals interviewing, so some ethical issues in relation to the participants and the researcher may have risen.

4. Company background

The previous literature review represents an attempt to formulate valid assumptions for our thesis. From the descriptions of the four stages, we come to the conclusion that CROWN Hellas Can S.A, Thessaloniki Plant, belongs to the Stage 2 companies, although we can, also, find some evidence from the other stages. In general, CROWN Hellas Can S.A tries to minimize the negative impact of maintenance and, sometimes, it is difficult to find team-oriented maintenance culture. Maintenance policies include both corrective and preventive maintenance and there is some kind of benchmarking with other plants of the group regarding the installation of new machinery which needs less maintenance during normal operation.

As far as CROWN Hellas Can is concerned, the maintenance capacity, mainly, involves permanent work force and management stuff, while there are three shifts during the summer months. The level of maintenance facilities is quite good with spare parts coming from either the internal warehouse or from external suppliers. Additionally, there is no condition monitoring technology and in-house maintenance is preferred. Concerning the infrastructure elements, the organization structure is centralized and the main maintenance concept is corrective maintenance despite the fact that there is an annual maintenance program in the plant. Moreover, there is CMMS; however the system needs reliable data in order to pay back. This kind of data after appropriate statistical processing will allow both the designation of the optimal equipment output and the implementation of preventive maintenance program.

A large percentage of experienced staff is reaching the retirement point and in combination with the existing organizational culture it is essential to push CMMS forward.

However, there are some other issues such as condition monitoring maintenance technology and CMMS usage which do need our attention. The main goal of the present thesis is trying to answer all these concerns through the use of Six Sigma tools for the appraisal of maintenance process in CROWN Hellas Can S.A.

It is common perception that if the maintenance process is of corrective character mainly, then it burdens the total costs and degrades the business performance. The main goal should be the introduction of preventive maintenance, which will contribute to the minimization of breakdown time, the reliable performance of equipment, the more convenient scheduling of the production process and the optimal utilization of human resources. In the case of CROWN Hellas Can S.A. we need to focus our efforts on the costs of conformance which are mainly associated with preventive maintenance and succeed in accomplishing valid preventive maintenance. In the long term, our goals of major concern should be the identification of both the weaknesses in our maintenance performance and critical machinery.

By adopting both the well-known method of problem solving DMAIC and the 6Sigma tools, an estimation of the present performance of the maintenance process is proposed in this thesis. In the next chapters, we will examine the way of each one of the individual five phases of the DMAIC methodology (Define, Measure, Analyse, Improve, Control) that contributes to the identification of deficiencies in the maintenance performance within Hellas Can.

Hellas Can S.A was founded by the multinational groups of MetalBox (UK), Continental Can (U.S.A), Carnaud (France) and the Greek banks ETBA and National Bank of Greece in 1965. The plants in Thessaloniki and Korinthos were built in 1969 and 1965 respectively. However, Hellas Can S.A acquired a third plant in Greece in 1999, more specifically in Patras, after the merger with a couple of Liberian firms which owned the 100% of stocks of the Alucanco S.A. Since 2003, the company has been part of the CROWN Holdings, Inc. and it belongs to the Europe, Africa and Middle East region from the administrative point of view.

The Thessaloniki plant used to be a vertical manufacturer of 3 pieces tinplate cans for food packaging (e.g. tomato, peach, olives, etc). Due to the fact that CROWN followed a retrenchment strategy worldwide a lot of plants had to either cease their operations or reassess their production activities. The above mentioned in combination with the increasing prices of metals in the world market and the non efficient performance of some departments within Hellas Can had a serious impact on the business strategy. The company needed to adopt a downsizing program and follow the competitive strategy of quality enhancement.

To support its business strategy the functional strategies had to be formulated in an appropriate way. This, also, applies to the case of maintenance strategy which needs to follow appropriate policy that will allow Hellas Can to gain competitive advantage over its competitors. This is valid not only in the local market, but in the international one too. It is worth mentioning that CROWN Turkish plants have to deal with, significantly, lower costs especially in terms of labour.

5. The implementation of DMAIC approach in the evaluation of maintenance variation in CROWN Hellas Can

5.1 Define phase

5.1.1 Scope

Based on our experience we believe that we have to make use of a bottom-up approach in order to select our project. This means to identify opportunities for improvement by the plant indicators. Among them we consider both the repair and the maintenance cost. By implementing the Define phase it becomes absolutely clear that we need to describe the problem the best way otherwise there will be no chance that we can solve it.

Our major issue of concern is the number of corrective jobs after the annual maintenance of the lines and, especially, during the summer period. It is absolutely clear that we have to use a scientific approach in the implementation of our maintenance activities; therefore we need to have documented evidence about which equipment is critical and what the real causes of defects are. Then, it will be possible to establish project objectives, since we will be able to focus our efforts on specific pieces of equipment.

Mainly, maintenance process provides service to the production function, so our project deals with the satisfaction of internal customers. Their point of view (Voice of the Customer) is important in order to achieve an appropriate problem assessment; however, we may need to overcome the organizational culture to succeed in gaining from their knowledge of the process.

The reason why we take this project on is to address the demand for cost reduction and this is possible to achieve through the savings depicted in the project charter form which is signed by both the plant manager and the finance controller. At an operational level our project supports the efforts for plant performance improvement and at a strategic level it is based on the demand that all business units of CROWN worldwide strengthen their competitive advantage in the local markets.

Define phase has been proven to be quite difficult since we realize that good problem statement and clear project objectives are not as easy as they seem to be. In our case we have to acquire a good knowledge of the maintenance process in a short period of time and to overcome the problem of lack of historical process data. The last one stands as an obstacle in our effort to `baseline´ the problem and set good goal statements.

Table 3 shows very clearly that it took us almost two weeks to finalize the project selection form and how much time was consumed for the preparation of the project charter form. Due to the fact that there is no process performance evaluation available it is obviously difficult to quantify how much the process will be improved. This is the reason why we decided to follow a conservative approach in the setting of the objectives and we have to keep in mind in the review of the goal statements at the end of Measure and Analyse phases to unsure they remain realistic.

Area of Accountability: Maintenance

Manager:Zapartas

Food Europe

Plant: Thessaloniki

ID	#	Activity Plan	August & September	October & November	December & January	Resp	Comments
		Define					Status on 10/10/2011
		Create Project Selection form					
		Create Project Charter form					Status on 10/10/2011
		Measure					Status on 10/10/2011
		Create new W.O's daily (CMMS)					Status on 10/10/2011
		Analyse, Imrove & Control					
		Create Defect trees for each line (CMMS)					Status on 10/10/2011
		Calculate the total breakdown time for each line					Status on 10/10/2011
		Implement Statistical Control (Minitab)					Status on 10/10/2011
		Know the cpk of each equipment					Status on 10/10/2011
		Suggest CAPEX list for critical equipment					Status on 10/10/2011

Planned Activity · No Progress · Activities Commenced · Action Completed & Objectives Achieved

Table 3: Action Plan.

5.1.2 Problem statement and project objectives

Below the problem statement and the project objectives are mentioned. At this point in the project it is difficult to quantify how much the process will be improved as there is no sufficient data to baseline the problem.

Problem statement: Annual preventive maintenance cost has been running at 130,000 Euros. However, machine breakdowns during either the high season or the trial initial start of the lines drive have increased operating costs (labour, repair cost), lost revenue and lower customer satisfaction.

Project objectives:

- Reduce the total number of defects by 5% by the end of January, 2012.
- Reduce the global breakdown time by 10% by the end of January, 2012.

5.1.3 Project team and stakeholders analysis

The formation of a good project team is not an easy task since the formal opening of the project takes place in the summer when the plant needs to achieve high production capacity. At the same time there are some other issues (e.g. forthcoming OHSAS 18001 certification) of high importance so it is not possible to have the appropriate people committed to the project.

Another important parameter to be considered when deciding the kind of people to be involved in the project is the organizational culture and this is the place where stakeholder analysis must be carried out. The business strategy of the last couple of years, as imposed by the corporate strategy, was the retrenchment and the subsequent consequence of the downsizing of the company. As a result some departments have a high esteem of their role and this contributes to no team-oriented maintenance.

On the other hand, we ought to recognize the contribution of the top management in the successful completion of the project and more specifically both the plant manager and the production supervisor provided the needed support. We wish that the same approach was kept by all the foremen, but this might not happen due to the fact that a lot of people were not familiar with the world-class performance concepts.

Name of Team Members:	Role:
Anastasios Derveniotis	Project Sponsor
Kostas Dimitriadis	Team member
Ioannis Falkos	Team member
Anna Giailaoglou	Team member
Gabriel Tatoglou	Process Owner
Zafeirios Zapartas	Project Leader

Table 4: Team members and their roles.

5.1.4 Voice of the customer

Maintenance improvement projects, usually, have to deal with internal customers. In our case, the service (maintenance) provider is the technical department (e.g. tool room workers, electricians, contractors, etc) and the customer is the production. It must be pointed out that to capture the Voice of the Customer (VOC) was another difficult task which we had to accomplish. We would rather use the direct contact methods like interviews at the point of provision instead of the less direct method of collecting feedback comments on the daily breakdowns submitted by the production supervisor. To compensate for this limited amount of information we have been based on the weekly technical meetings and personal observations on the shop floor.

Moreover, we, ourselves, became a customer in order to make an assessment of the personnel's needs in the can lines department and to identify Critical to Quality characteristics (CTQs), which should be addressed by the outputs of our process. For instance, take a glance at the following examples:

- Maintenance Manager says: *"I have no feedback about actual situation"*.

  CTQ ⟹ The more frequent defects and the corresponding breakdown times are …

- Accounts Manager says: *"Maintenance is to be blamed for the increased repair cost"*.

  CTQ ⟹ The repair cost should be less than 247.848,6 Euros per year.

- Maintenance Manager says: *"We need to monitor the breakdown time"*.

  CTQ ⟹ The breakdown time should be less than 0.5 hours per defect.

- Plant Manager says: *"There is no historical data about annual maintenance"*.

  CTQ ⟹ Enter all data in CMMS system

5.1.5 High level Process Mapping

The following figure illustrates the core process which our project is focused on. It is not a detailed one and helps ensure that everyone involved understands the suppliers

(S), their inputs (I), the process (P), the outputs (O) and the corresponding customers (C).

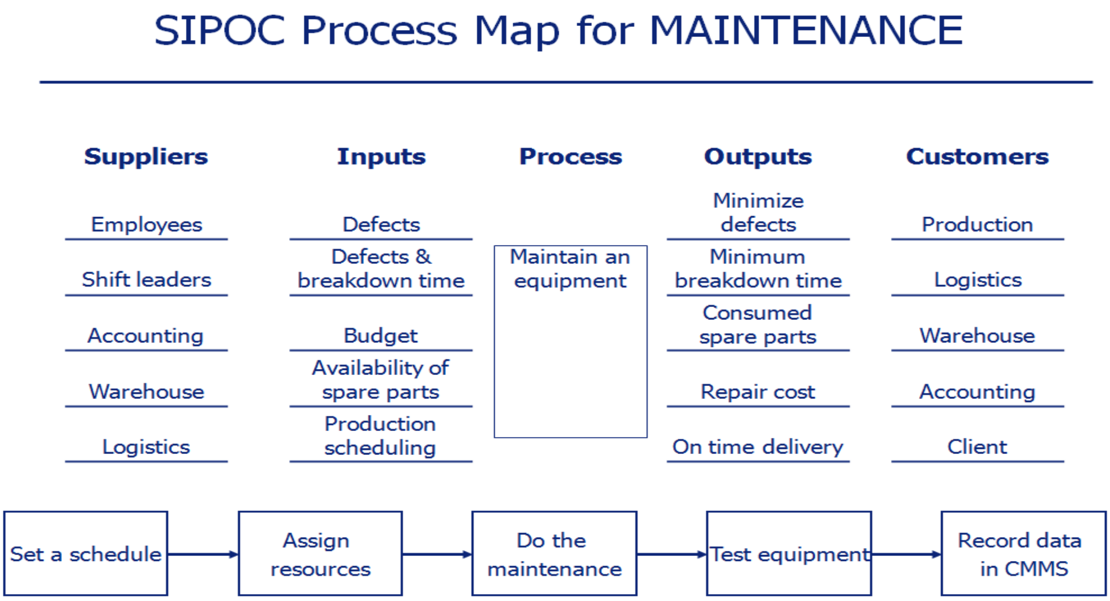


Figure 9: The SIPOC map of the process.

5.1.6 Project charter

The next document is summarising the findings of the Define phase of our project. It is worth mentioning that it took us quite long to complete the Define phase and this might be understood by the obstacles that we needed to overcome such as the absence of relevant data, the non familiarity with the concepts of WCP (world class performance) and the period during which we had to accomplish the project (high production capacity due to the seasonality of the market). Additionally, we should consider that at the same period of time another project was running regarding plant's OHSAS 18001 certification.

Project Charter

Project Title:	Identification of critical equipment

Project Team		Stakeholders	
Role	Name	Role	Name
Project Sponsor	Anastasios Derveniotis	Six Sigma Champion	Zafeirios Zapartas
Project Leader	Zafeirios Zapartas	Process Owner	Gabriel Tatoglou
Team Members		Shop floor foreman	Nikos Karapidakis
	Kostas Dimitriadis	Shop floor foreman	Pavlos Sidiropoulos
	Ioannis Falkos	Shop floor foreman	Vasilis Chatzibougatsas
	Anna Giailoglou	Electricians' foreman	Stavros Theodosiadis
	Gabriel Tatoglou		

Problem Statement	Goal Statement
Annual preventive maintenance has been running at 130,000 Euros. However, machine breakdowns during either the high season or the initial trial start of the lines drive increased operating costs (labour, repair cost), lost revenue and lower customer satisfaction.	1. Reduce the total number of defects by 5% by the end of January, 2012. 2. Reduce the global breakdown time by 10% by the end of January, 2012.

COPQ Summary	VOC - key customers
The non efficient maintenace process downgrades the satisfaction of the operators and increase both the labour costs of rework and the costs of capital tied up in spares in case of an emergency breakdovn. Morever, there the costs of increased energy consumption and of low line efficiency which have been estimated to be 3,700 Euros for the period of 10/2011 up to 1/2012.	Maintenance manager: "*I have no feedback about actual situation*". Accounts manager: "*Maintenance is to be blamed for the increased repair cost*". Maintenance manager: "*We need to monitor the breakdown time*". Plant manager: "*There is no historical data about annual maintenance*".

Scope	Project Plan	Plan	Actual
Can Lines department	Start of project	1/8/2011	1/8/2011
	End of Define	12/8/2011	14/10/2011
	End of Measure	15/9/2011	31/10/2011
	End of Analyse	30/11/2011	
	End of Improve	14/12/2011	
	End of Control/Project	31/1/2012	

Status: 16/12/2011

Table 5: The Project Charter.

5.2 Measure phase

5.2.1 Scope

The final aim of the measure phase is to baseline process capability and potential through the development of clear and meaningful measurement systems. The first obstacle we need to overcome is how we are going to measure the current process performance since there are neither established KPIs (Key Performance Indicators) nor data collection plans in place.

Hellas Can has not been making use of a reliable method of recording either the breakdown times or the reasons behind them, which would allow us to understand the historical `behaviour´ of the process. However, there is still a book in the shop floor office which is used to have the line stops written down by the production foremen and based on this kind of information the logistics supervisor is able to provide by categorizing the hours of lines stoppages based on the machine which had the defect.

We have been using CMMS (Computerised Maintenance Management System) software which can provide us reports concerning defect trees since 19th of May, 2011 (pilot start of COSWIN software). In this way, we are able to produce different kinds of reports and charts which can be found in the following chapters of this thesis.

5.2.2 Key Performance Indicators (KPIs)

As previously mentioned, we need to develop metrics, either called KPIs, which reflect the performance of the process. The terminology‟ KPI˝ is widespread in a variety of issues (e.g. safety etc) and, in any case, KPIs should be customer driven. Based on the Critical to Quality (CTQ) features derived from the Voice of Customer (VOC), we come to the conclusion that the kind of data we need to collect are the breakdown time and the number of defects.

The following paragraph provides the operational definitions of our KPIs which are mainly associated with the effectiveness of the process in the eyes of the customer. The customer is an internal one, the operator of the can lines department, and he wishes the smooth performance of the whole equipment. However, a project should also have some KPIs that reflect the efficiency of the process from the business perspective and such one could be the cost of poor maintenance (CoPM) and especially the costs related to unnecessary preventive maintenance. So, it is quite clear that we need to achieve a balance of measures covering delivery, quality and cost.

KPI 1: Breakdown time (hours)

What does the KPI represent: The time elapsed between the stoppage of equipment due to a defect and the restart of it for normal performance.

Detailed definition:

Beginning of time – the time when a defect occurs and the equipment fails to meet the required standard forcing the operator to either repair it himself or call for technical assistance.

End of time – the time that the equipment runs under normal production.

KPI 2: Number of defects (occurrences)

What does the KPI represent: The number of occurrences of a specific kind of defect.

Detailed definition:

The defects have been categorized according to the kind of technical issue of them.

The KPI 1 belongs to the `continuous´ data because it is related to the measuring of a service characteristic, while the KPI 2 is of `count´ data as it results from counting things. It is very important to know the different kinds of data involved in our project as it has implications for the type of tools and techniques that will be used later on during the project.

5.2.3 Data Collection Method

The above mentioned operational definitions lead us to the conclusion that the existing data source (hand written book called `Book of Events´ at the shop floor office) cannot be used. Moreover, there is not any data collection system integrated into the process and therefore it is essential to establish a manual system for the duration of our Six Sigma project.

We made the decision to design a check sheet which will be based on an existing table (Table 6) used to make the reports for defect trees. While designing this check sheet, we were kept in our mind that we should follow the principle as simple as possible (ASAP). Additionally, we needed to ensure traceability of data which means that we had to record dates and numbers of work orders related to each one defect. This is useful contextual data providing as much information about process events as possible.

Code	Symptom	Code	Defect	Code	Cause	Code	Action
ELEC	Electrical	CONS	Construction Problem	TOOLD	Too Old	EMERC	Emergency Repair
MECH	Mechanical	MAINT	Maintenance Problem	WAER	Wear	CNEW	Change to New
HYDR	Hydraulics	OVERL	Overload	POLLU	Pollution	NOSPA	No Spares available
PNEU	Pneumatic	WEAR	Wear	SKILLS	Employee skills	EXTERN	Extern Supplier ordered
TOOL	Tooling	LEAK	Substances leaks	MAT	Wrong material	REPL	Replacement
CHILL	Chillers/coolers	TEMP	Overheating	SETT	Wrong machine setting	MODI	Modification
QUAL	Quality problem	BMAT	Materialquality	IMPR	Improvement	RESE	Re-setting
NMAT	No Material	ELSC	Electric short circuit	CMAT	Material changed		
NPER	No Personal	ELIM	Elimination / Separation	UNDD	Unterdimensions		
OOSP	Out of Specification						

Table 6: The guide for building defect trees.

Table 7 illustrates the check sheet used to record data and each one of the can lines had its own sheet. It may be made either in Excel or Minitab software, in order to have the data statistically processed and produce relevant reports and charts. It is obvious that it contains more data than the KPIs described above as this information will be essential later on in the Analyse phase of the project.

# Work Order	Date	Breakdown time	Symptom	Defect	Cause	Action

Table 7: The check sheet for recording data.

5.2.4 Measurement System Analysis (MSA) Drilldown

The measurement system used during our project was not a complicated one. The data had been collected daily as the result of collaboration between the Can Lines Supervisor and the CMMS coordinator in order to record all defects and relevant breakdown times.

The quality of data had been an issue of major concern. We needed to ensure that everything entering the COSWIN database was reliable and this was the main reason we had to pay regular visits to the shop floor and have interviews with the employees in order to discover what the real causes of defects had been. On the other hand, the number of occurrences of defects was easy to be recorded.

However, one potential source of error had been the breakdown time as there was not any established system (e.g. the press of a button) which could trigger the measuring of it.

5.2.5 1st Pass Analysis

Before proceeding to the Analyse phase, it is useful to make a simple evaluation of the current preventive maintenance performance. Based on the paper published by Pintellon, L. and Puyvelde, F.V. (1997), we consider the process (e.g. the whole of maintenance activities) of annual maintenance of Can Line 02 (Appendix F) and we calculate the following performance indicators:

Efficiency = $\frac{theoritical\ input}{actual\ input} * 100\% = \frac{\left(13\ workers*\frac{8h}{day}*17days\right)+(3workers*\frac{8h}{day}*5days)}{1662workers*hours} * 100\% = \frac{1768workers*hours+120workers*hours}{1662workers*hours}$*100% ≈ 1,135*100% ≈ 114%

Effectiveness = $\frac{actual\ jobs\ done}{theoritical\ jobs\ done} * 100\% = \frac{65}{165} * 100\%$ = 39.4%

Productivity theoretical = $\frac{theoritical\ jobs\ done}{workers*8hours/day} = \frac{165}{1888} = 0.0874$

Productivity actual = $\frac{actual\ jobs\ done}{workers*actual\ hours/day} = \frac{65}{1662} = 0{,}039$

Productivity index = $\frac{Productivity^{actual}}{Productivity^{theoritical}} * 100\% = \frac{65}{1662} * 100\% = 3.91\%$

The actual jobs done are those mentioned by the mechanics and operators and can be found as comments in the Work Order #935 (Appendix D). On the other hand, the theoretical jobs done are coming as preventive ones from the CMMS.

Moreover, we provide the histograms of all the can lines in order to have an understanding of maintenance performance for each one of them (Appendix B).

5.2.6 Capability Analysis

The Capability analysis will be conducted for data which was collected for the specific project and we took care that data is displayed in time order. However, our small sample of measurements reflects only the short term performance of the process (maintenance activities).

➢ Can Line 01

The histogram of the data (see Appendix B) indicates that the process distribution is skewed and the Normality Test also indicates that the data is not Normally distributed. So, we must choose the Minitab's Non-Normal Capability analysis function and select the appropriate distribution that best fits the data sample.

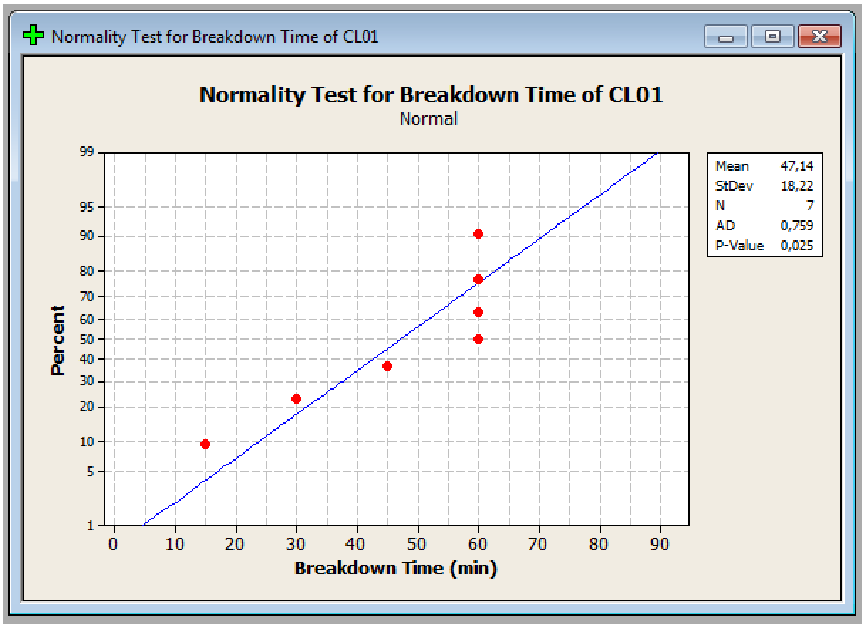


Figure 10: Normality test for breakdown time of CL01.

The 3-parameter Weibull curve shown in Figure 11 appears to fit the shape of the histogram reasonably well and so we can assume that the expected overall performance figures will be reasonably reliable.

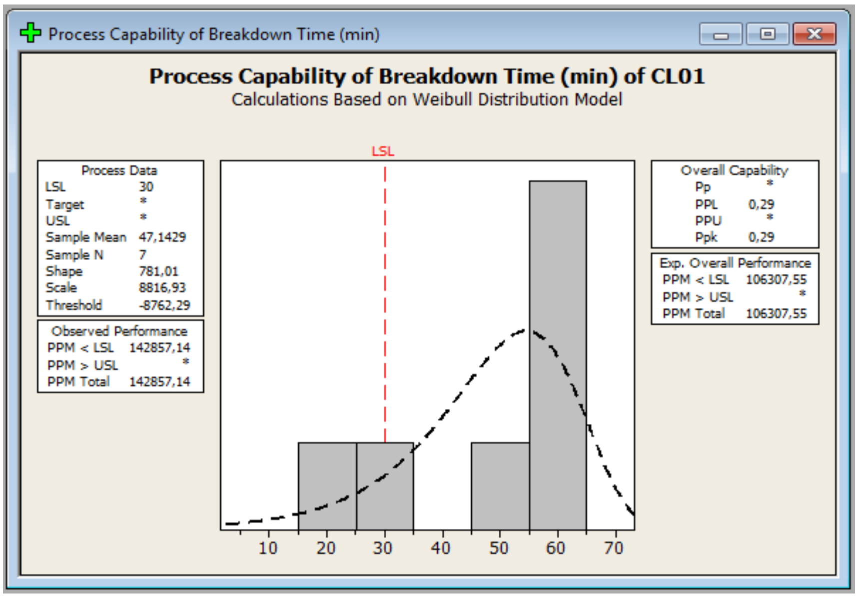


Figure 11: Process capability of breakdown time of CL01.

Observed performance statistics are based on the results within the data sample collected for CL01. In this case 14 Breakdown Times (out of 100) took less than 30 minutes. This 14% is equivalent to 142,857.14 parts per million. Also, the expected performance figure predict that 106,307 parts per million will be below the LSL if the process continues as it is. 106,307 PPM is the same as 10.6%.

P_{pk} is similar to the C_{pk} statistic and a value of 0.29 indicates that this process is not `capable´ for the longer term. Minitab provides just an asterisk for `PPM>USL´ since there was no upper specification limit (USL).

➢ Can Line 02

In order to make the right kind of capability analysis we have to determine the kind of data under study. For this reason, we apply the Anderson Darling Normality Test for the breakdown time data of Can Line 02 and, since, the p-value (0.123) is greater than 0.05, there is a reasonable chance that it could be Normally distributed and so we usually assume it is.

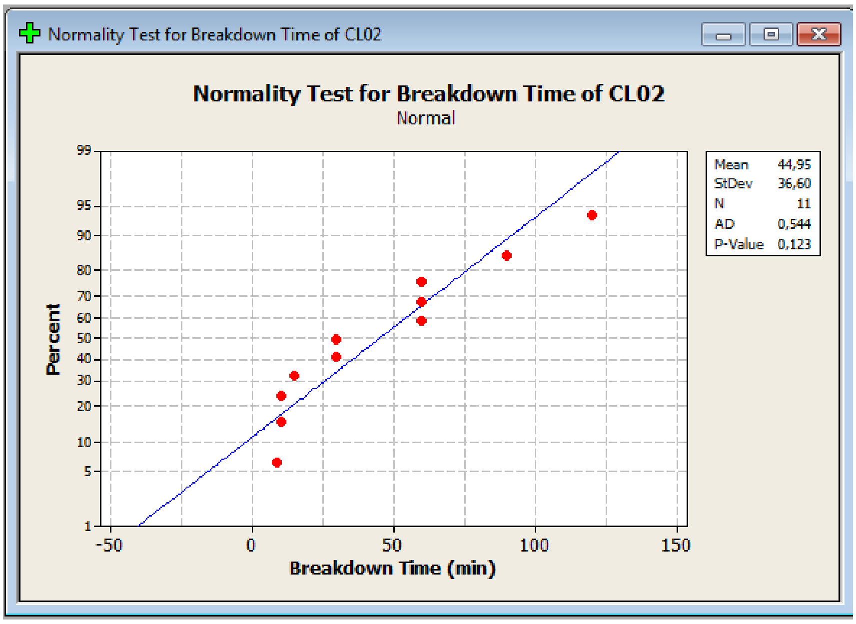


Figure 12: Normality test for breakdown time of CL02.

We set the Lower Specification Limit (LSM) to 30 minutes and the Upper Specification Limit (USM) to 90 minutes concerning the breakdown times. This complies with one objective which is the reduction of the percentage of occurrences of defects which take longer than 30 minutes. We enter the data to Minitab and we have the report of the Figure 13.

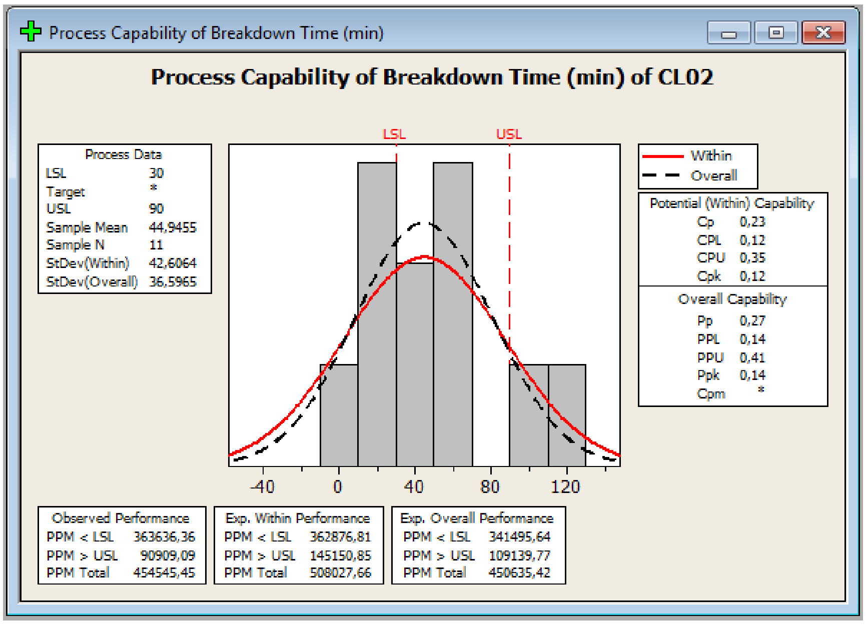


Figure 13: Process capability of breakdown time of CL02.

The analysis found a small difference between the short term variation (standard deviation = 42.61) and the long term variation (standard deviation = 36.6). The two Normal curves reflect this difference – the dashed line represents the long term (it is narrower/taller) and the solid line represents the short term. According to observed performance figures, 36.36% of the defects took less than 30 minutes

- Can Line 05

The distribution of breakdown times of CL05 is right (positive) skewed (see Appendix B) and the application of the Normality Test also indicates that data is not Normally distributed (Figure 14).

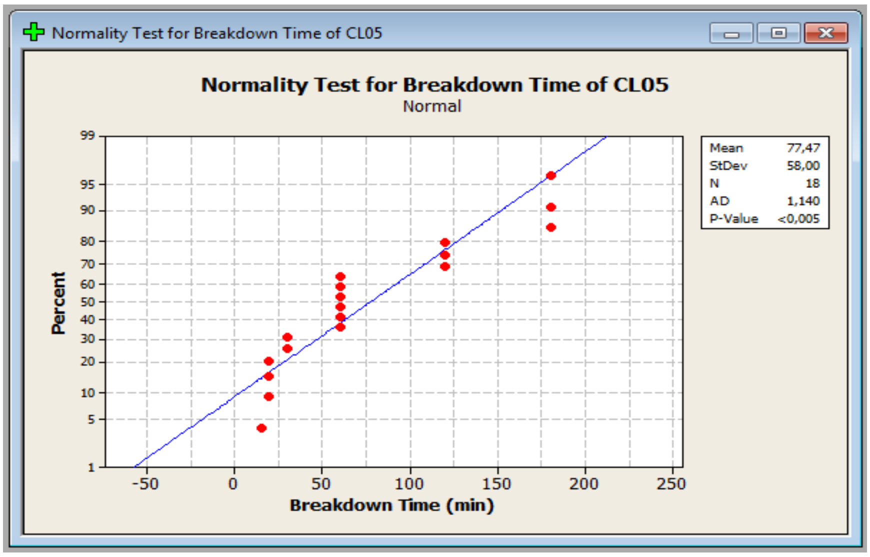


Figure 14: Normality test for breakdown time of CL05.

Before we apply Minitab's Non-Normal Capability analysis function it is essential to perform the Individual Distribution Identification function in order to find the distribution that best fits our data sample. Next figure depicts the relevant window from Minitab and the subgroup size is of 1 since our data was not collected or sampled in rational subgroups.

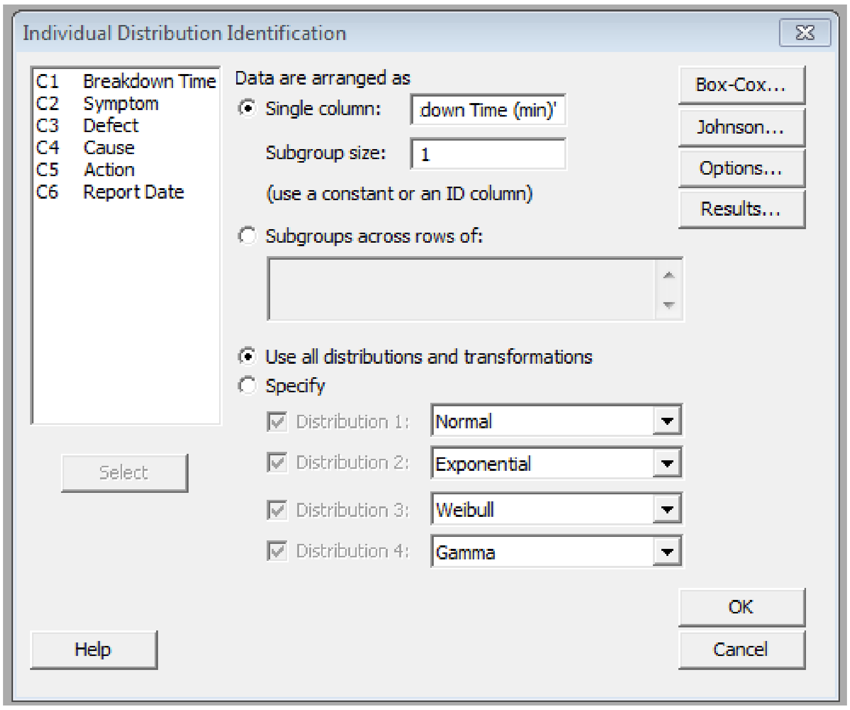


Figure 15: Individual Distribution Identification window of Minitab.

Minitab produces the numerical report of Figure 16 which is supported by probability plots of the sample data against each one distribution of the specific report. In this case, there are two distributions (excluding the transformations) that would provide a reasonable fit for the data (i.e. they have p-values well above 0.05). They are the Exponential and 2-Parameter Exponential distributions.

However, the Expected Performance statistics cannot be a very reliable prediction since the fitted model is not very suitable. On the other hand, according to the Observed Performance statistics, almost 22 of the 100 Breakdown Times took less than 30 minutes which is the lower specification limit (222,222.22 PPM).

```
Box-Cox transformation: Lambda = 0

Johnson transformation function:
0,650423 + 0,550963 * Ln( ( X - 14,6768 ) / ( 223,979 - X ) )


Goodness of Fit Test
```

Distribution	AD	P	LRT P
Normal	1,140	<0,005	
Box-Cox Transformation	0,638	0,081	
Lognormal	0,638	0,081	
3-Parameter Lognormal	0,728	*	0,445
Exponential	0,897	0,145	
2-Parameter Exponential	0,553	>0,250	0,017
Weibull	0,708	0,056	
3-Parameter Weibull	0,635	0,101	0,141
Smallest Extreme Value	1,457	<0,010	
Largest Extreme Value	0,922	0,017	
Gamma	0,703	0,077	
3-Parameter Gamma	0,641	*	0,224
Logistic	1,081	<0,005	
Loglogistic	0,669	0,046	
3-Parameter Loglogistic	0,758	*	0,262
Johnson Transformation	0,517	0,165	

Figure 16: Individual Distribution Identification – Data output.

Based on the 2-Parameter Exponential distribution, Minitab produces the report of Figure 17.

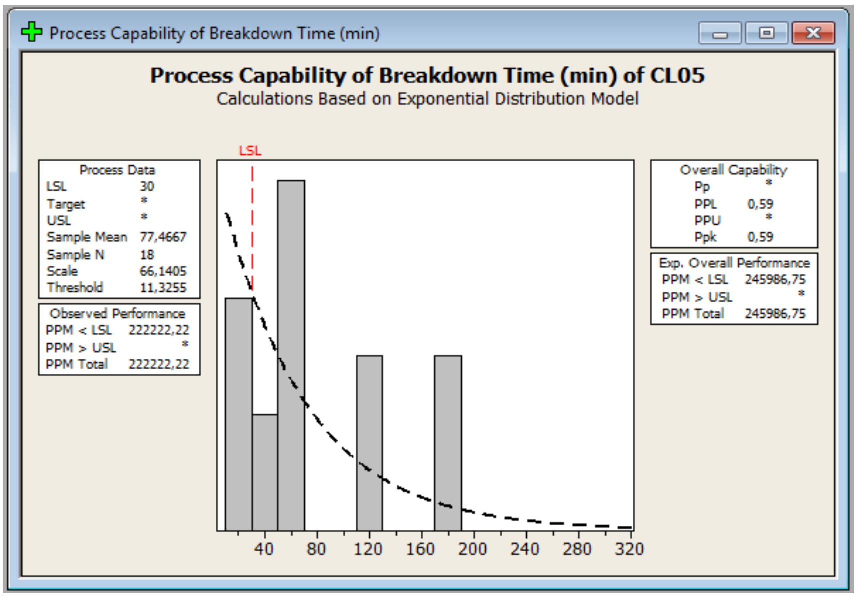


Figure 17: Process capability of breakdown time of CL05.

➢ Can Line 06

The application of Anderson Darling Normality test shows that breakdown time data is not Normally distributed (Figure 18).

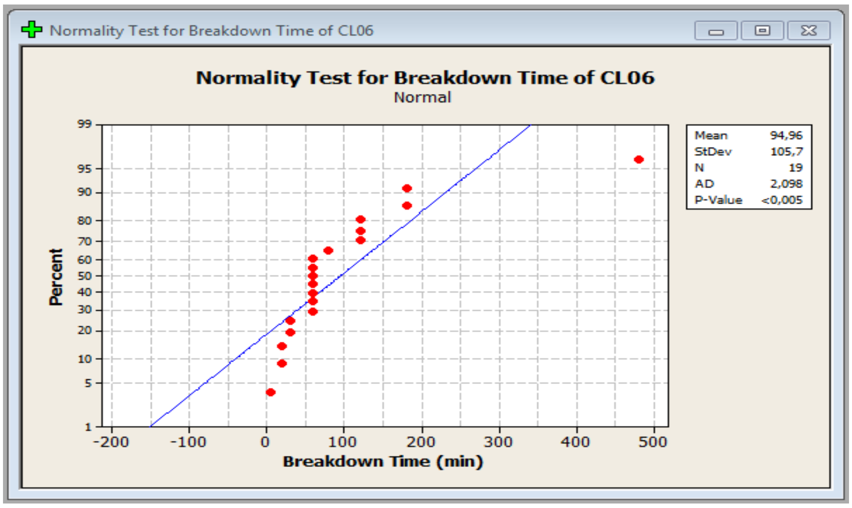


Figure 18: Normality test for breakdown time of CL06.

We compare the column of breakdown time data against a number of different distributions by using Minitab's Individual Distribution Identification function. As in Can Line 05, we find that Weibull distribution is a good fit for the data, as illustrated in Figure 19.

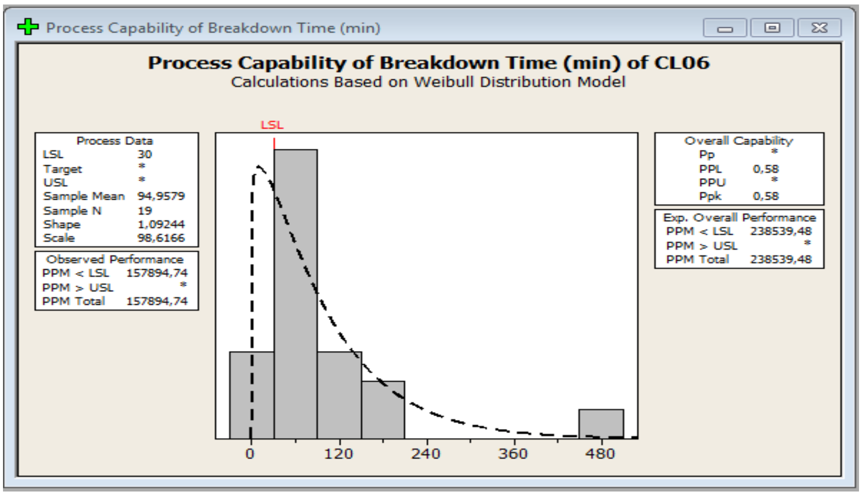


Figure 19: Process capability of breakdown time of CL06.

Based on the analysis of the data sample, almost 16% of the Breakdown Times took less than 30 minutes. This is equivalent to 157,894.74 PPM.

5.3 Analyse phase

5.3.1 Scope

This is, perhaps, the most important phase of our project since we must verify the root causes of defects. The first stage involves analysing the process and discovering what the existing process knowledge says. The second stage copes with the analysis of data and the establishment of relationship between the process output (symptom/defect) and the cause of it.

In contrast with the two, previously, mentioned phases (Define and Measure) the Analyse phase functions more as a toolbox of tools and techniques and we have to choose the right one. The first stage aims to understand how the process itself works, while the second stage focuses on analyzing the data.

As far as the first stage's techniques are concerned, we are going to make use of affinity diagrams and measles charts to understand what does go wrong in the process and where. Finally, in the second stage we will apply a range of graphical and statistical tools to analyse the data.

5.3.2 Affinity diagrams

During the Measure phase, we have implemented the check sheet of Table 7 which asks for the details of a symptom to be written down. The *`Details Equipment Defects´* reports produced by CMMS (see Appendix A) may be named affinity diagrams as it is possible to find similar groups within these sorts of textual (non numeric) data.

Regarding the *`Details Equipment Defects of Can Line 01´*, the biggest cluster is that of the Figure 20 and it can be focused on for problem solving.

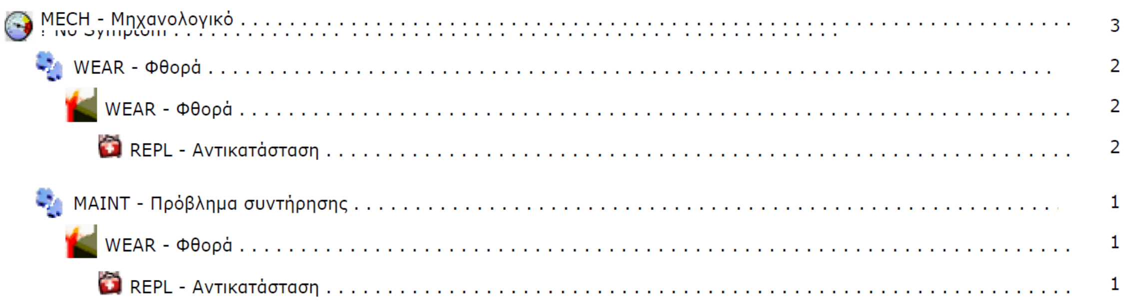


Figure 20: Biggest cluster of CL01.

Figure 21 illustrates that part of the `*Details Equipment Defects of Can Line 02´* report which represents the cluster with the highest number of occurrences.

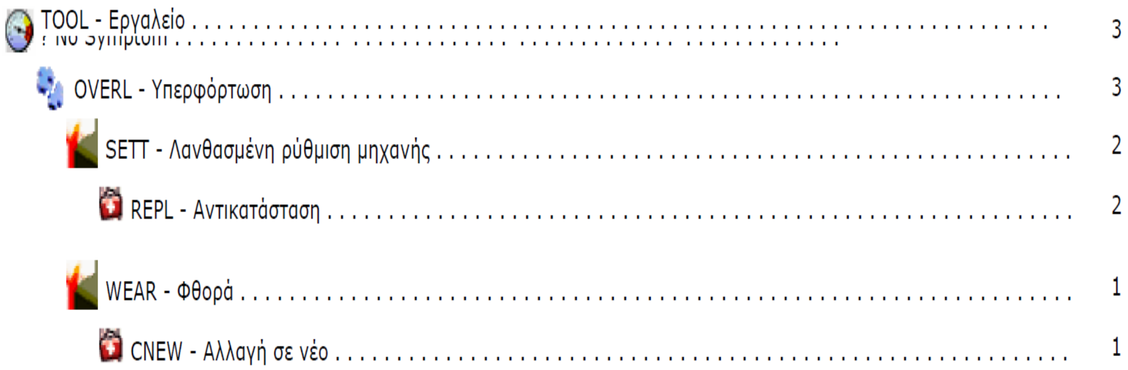


Figure 21: Biggest cluster of CL02.

Concerning the Can Line 05, there are more clusters of high interest and they are depicted in the figure below.

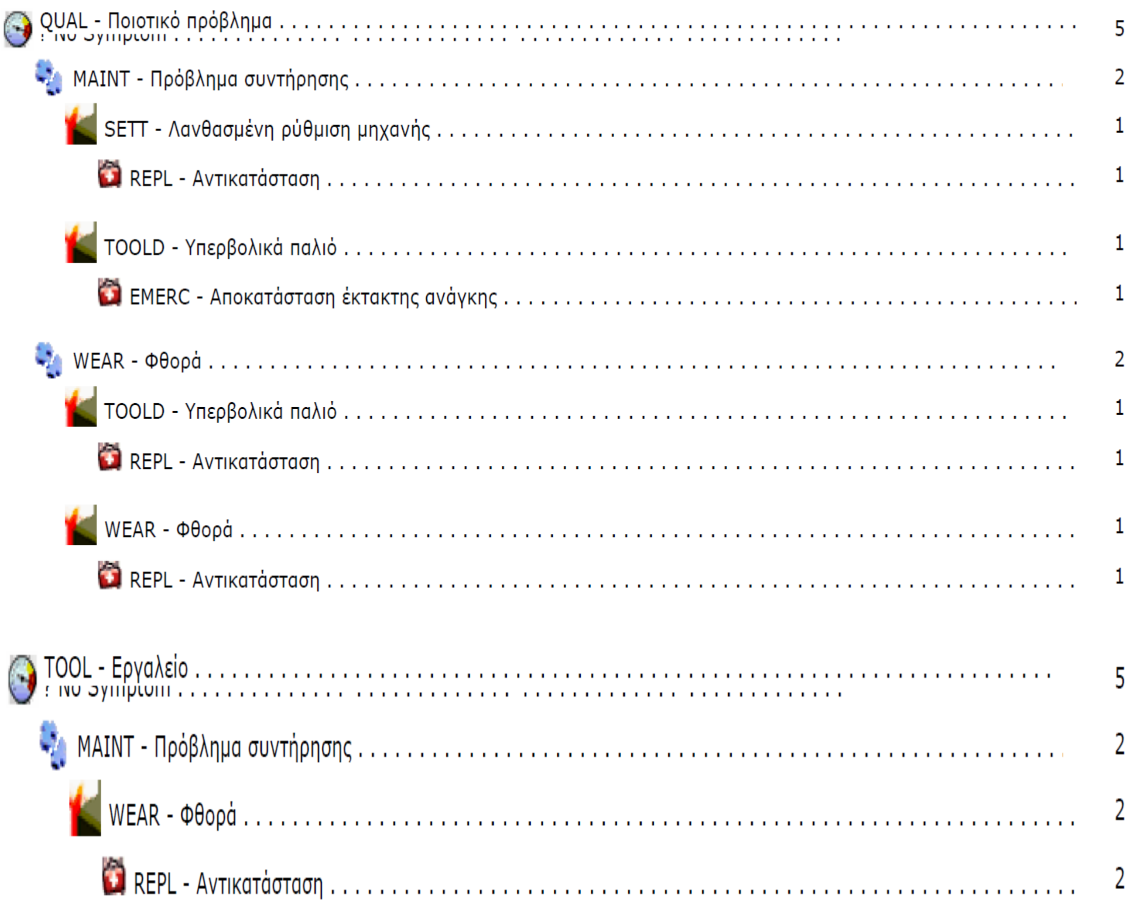


Figure 22: Biggest clusters of CL05.

Can line 06 is of the same concern with Can Line 05 as it has a couple of clusters which are quite interesting based on the Figure 23.

Figure 23: Biggest clusters of CL06.

5.3.3 Histograms

Histograms of Breakdown Time for all the can lines can be found in Appendix B as they had been constructed on the basis of the data collected during the Measure phase. The minimum sample size for a histogram is 25, yet we produced histograms based on small sample sizes and histograms with few columns came as a result.

Also, the non-normality of the most data samples (except for CL02) is an indication of the fact that we do not have yet big sample sizes. It seems that the Breakdown Time is measured in five minutes intervals and this is affecting the Normality of data since the values tend to group in exactly the same number.

5.3.4 Pareto charts

Pareto charts are essential on gaining clues and understanding from the process data itself. Going back to the Measure phase (Table 6), it is obvious that Pareto charts will help us identify the most common categories in the column of textual data related to the different kind of defects.

In the Can Lines department, `Maintenance´ is the most frequent reason for equipment defects with 25 found (45.5%) and `Wear´ is the second most frequent with 17 found (30.9%). Together, (cumulatively) they represent 76.4% of the defects found – shown by the cumulative curve (Appendix C). The 80/20 Principle can be seen to some extent in our project, since the first two reasons of defects (out of 6) create 76.4% of the machine breakdowns.

Can Line 01 appears to have the fewer kinds of defects (totally three) with total number of occurrences seven. It is followed by Can Line 02 with four kinds of defects and eleven occurrences. However, Can Lines 05 and 06 are of major concern since they demonstrate all the kinds of defects and, especially, those related with wear and maintenance. In details, maintenance and wear defects are related to twenty nine occurrences.

5.3.5 Individual value plot

Individual value plots will be used to comparing breakdown times distributions against each other and since our sample sizes are low (<25). As illustrated in Figure 24, we can spot an outlier on the distribution of data of CL 06. Also, the smaller sample size of the CL 01 is immediately obvious with the specific Individual Value Plot.

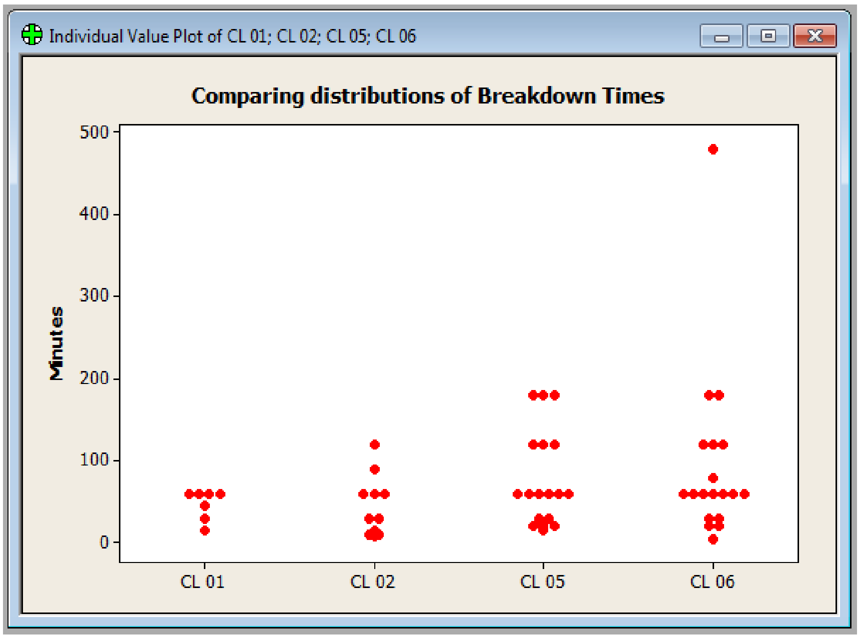


Figure 24: Comparing distributions of Breakdown Times.

5.3.6 Scatter plot

All the tools for analyzing the data graphically are very useful since they allow us to investigate whether a `relationship´ exists between two factors. In this way, we will be able to suggest improvements during the Improve phase of our project. We sum up the total occurrences of defects and the total breakdown time for each Can Line separately and we have the diagram of Figure 25. According to this, a relationship *appears* to exist where the higher the number of occurrences of defects, the higher the total breakdown time.

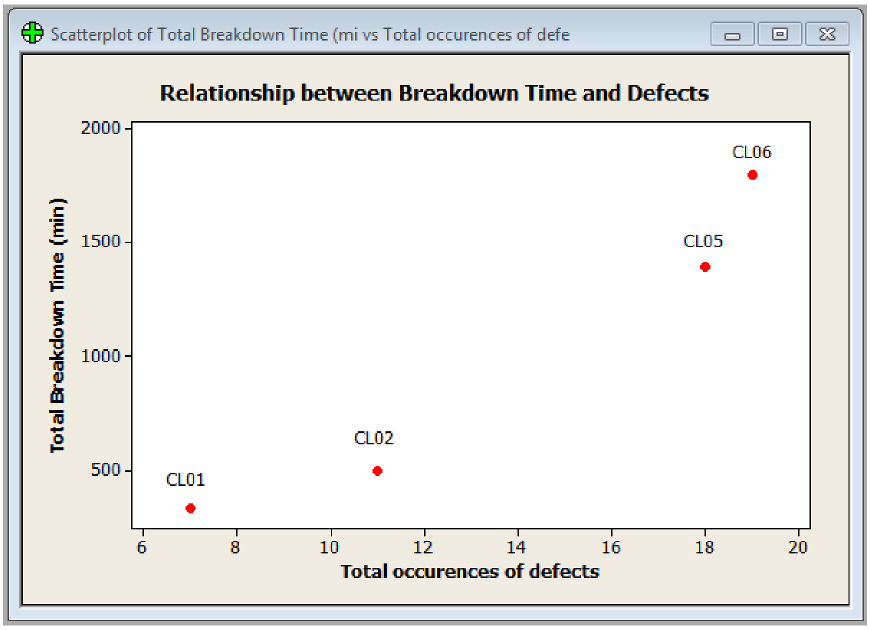
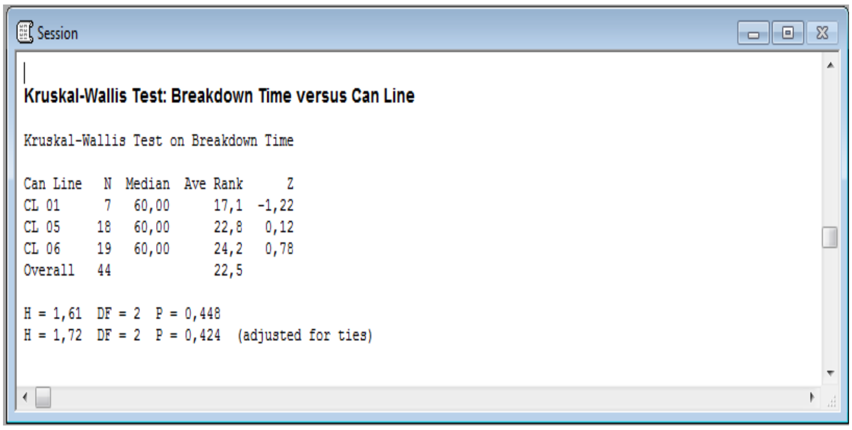


Figure 25: Relationship between Breakdown time and total defects for each Can Line.

It seems rational that more occurrences of defects will contribute to higher breakdown time. However, we should avoid concluding that a `direct cause and effect´ relationship exists since this would mean that all kind of defects are of equal impact on the performance of the line.

5.3.7 Kruskal-Wallis Test

We perform this test in order to compare the medians of data samples of CL01, CL 05 and CL06 which are not Normally distributed, as shown in capability analysis of Measure phase. Minitab produces the Session window results of the Figure 26.



Session

Kruskal-Wallis Test: Breakdown Time versus Can Line

Kruskal-Wallis Test on Breakdown Time

Can Line	N	Median	Ave Rank	Z
CL 01	7	60,00	17,1	-1,22
CL 05	18	60,00	22,8	0,12
CL 06	19	60,00	24,2	0,78
Overall	44		22,5	

H = 1,61 DF = 2 P = 0,448
H = 1,72 DF = 2 P = 0,424 (adjusted for ties)

Figure 26: Comparing the medians of samples from CL01, CL05 and CL06.

It is obvious that there is no difference in the median values and this means that we should be more precise in the recording of breakdown time, as it was explained above in the histograms paragraph. The p-value from this test is 0.463 and since it is higher than 0.05, we prove the already shown that we cannot say with confidence that there is a difference in the medians of the three samples.

5.3.8 Simple regression

As we can see from the scatter plot above, it would be useful to create a line that best resembles the relationship between the Total (global) Breakdown Time and the total number of defects. Due to the fact that this line could not pass exactly through all of the data points the best line is found by ensuring the errors between the data points and the line are minimized (`line of least squares´).

The scatter plot of Figure 25 suggests a positive correlation between the total occurrences of defects and the Total Breakdown Time. Minitab's Fitted Line Plot can be used to perform simple regression in order to model the relationship between the previously mentioned variables.

We choose the Linear Regression Model, based on the scatter plot of Figure 25. In our case (Figure 27):

- The Total Breakdown Time is the process output (the Response – Y)
- The total occurrences of defects is the process input (the Predictor – X)

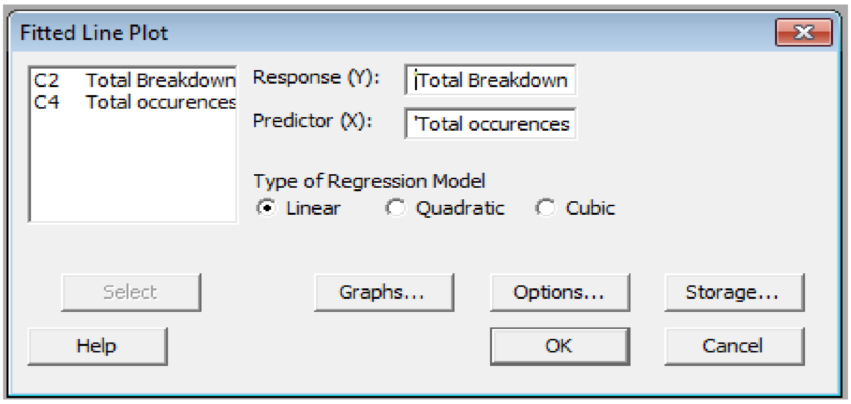


Figure 27: Fitted Line Plot – Data input window.

The regression equation is:

Total Breakdown Time (min) = -638.7 + 119.6 * Total occurrences of defects

This equation can be used to predict the Total Breakdown Time (min) that will arise for a specific number of defects. The constant 119.6 (slope of the line) is the increase in global breakdown time for an increase of 1 defect in the total occurrences of defects (Figure 28).

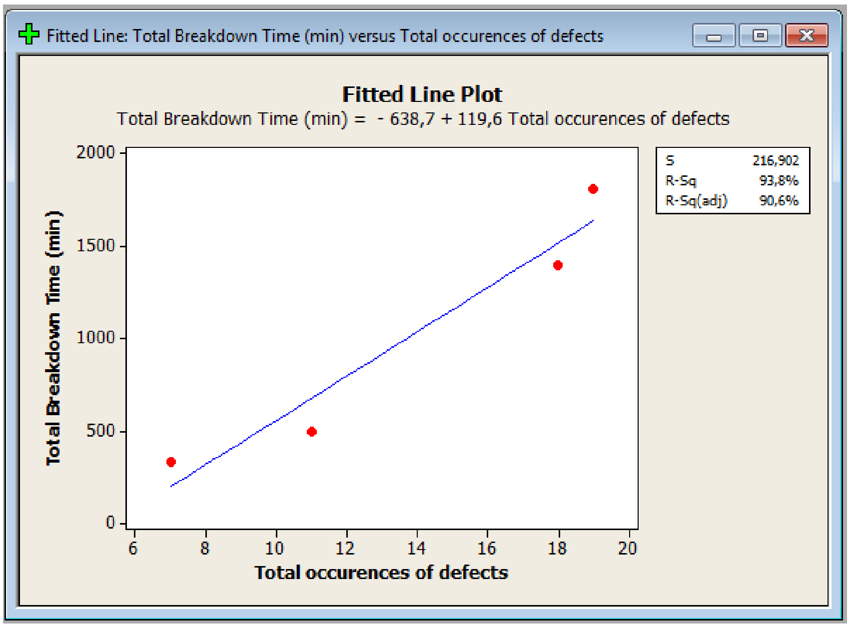


Figure 28: Fitted Line Plot – Data output window.

In any case, we should keep in mind that we need to avoid using the model beyond the data used to create it in order to predict future process (maintenance) performance.

5.4 Improve phase

5.4.1 Scope

The Improve phase aims to give answers to questions such as what improvements can we make, can we create a model of the process relationships or are we able to prove our gains.

First of all, we will rely on conclusions reached from analyse phase to generate potential solution(s) and then decide which solution(s) are most likely to work based on specific assessment criteria and the expertise from the Can Lines department supervisor. Afterwards, we will assess the risk of implementing the solution(s) and plan the pilot implementation and management of change.

It is worth mentioning that our data collection system developed in measure phase remains in place. Due to the fact that our case study is part of an ongoing project, the success of the Improve phase will be determined by the improvement of the KPIs and the consequent validation with appropriate statistical techniques.

5.4.2 Generate potential solutions

5.4.2.1 Negative brainstorming

We assume that we deliberately want to create a bad maintenance service in order to find out the root causes of the bad performance and suggest potential solutions. So, focusing our interest on the key outputs of the process (Figure 9), ask;

- ‶ how can we deliver bad maintenance to our production department (internal customer)?″
- ‶how can we make sure that we do not record data the appropriate way?″
- ‶how can we make sure that we do not repair the defect the first time?″
- ‶how can we make sure that we do not apply valid preventive maintenance?″
- ‶how can we make sure that we do not minimize repair costs?″

Based on both the histograms of breakdown times and the Pareto charts of defects and causes, we come up with the answers to the previous questions:

- Convince people to record all data as precisely as possible by making use of suitable form (Table 7)
- The can lines of main interest are CL05 and CL06 since they *appear* to demonstrate the most defects and relevant causes
- Reduce the percentage of defects related with maintenance and wear causes (76.4% of the total defects)
- Reduce the percentage of causes related with wear and wrong machine settings (70.9% of the total causes)
- Improve people skills (7.3% of the total causes is linked with employees' skills)

5.4.2.2 Select the best solution

The outcomes from the negative brainstorming are the assessment criteria for selecting the best solution for the project. Besides, we need to assign specific weights to our assessment criteria and, then, score each one of the suggested maintenance strategies against the already developed criteria.

5.4.3 Failure Mode Effect Analysis (FMEA)

The FMEA is used to identify and assess the risks of either existing or proposed controls in a process. For each potential failure mode, we consider the potential causes that might cause the failure and rate their severity (SEV), their occurrence (OCC) and their likelihood of detection (DET). Then a Risk Priority Number (RPN) is calculated for each potential failure by multiplying the severity by occurrence by detection.

We analyse the outputs (Figure 9) of the process and take into account the potential failure effects, causes and controls of each one potential failure mode. Table 8 illustrates the FMEA for our process.

Process
Failure Modes and Effects Analysis (FMEA)

Process Name: **MAINTENANCE** FMEA Date (Orig) ______ (Rev) **22/01/12**

Process Step or Product Part	Potential Failure Mode	Potential Failure Effects	SEV	Potential Causes	OCC	Current Controls	DET	RPN	Actions Recommended	Resp.	Actions Taken	SEV	OCC	DET	RPN
Record breakdown time	Not precise recording	Wrong histograms	2	1. Lack of time 2. Lack of training	8	Form	9	144	Better supervision of current controls						0
Repair a machine	Not fix it the first time	Low performance	7	1. Lack of expertise 2. Lack of appropriate	2	Manufacturer's manual(s)	3	42	Training						0
Use spare parts	Not of the correct type	1. Low performance 2. Reduced credibility	7	1. Local manufacturer 2. Shortage	3	Frequent checks of stock level	3	63	1. Bar code system 2.CMMS follow-up						0
Delivery of service	Not on time	Low performance	8	Busy schedule	2	Appropriate scheduling	1	16							0

Table 8: FMEA of the process.

5.4.4 Pilot study

In the first phase the scope of our pilot study should be limited to CL02 in order to test the effectiveness of the solution before full implementation. This is logical since the Capability Analysis showed that the Normal distribution is behind the sample data and so it is possible to apply many of the tools and techniques in a statistically valid manner.

The right period for the pilot would be the beginning of high season (early May) since the timeframe will be sufficient for the process to respond to the solution implemented and the amount of collected data will be sufficient enough to reach statistically valid conclusions. At the same time, the low change over rate will give us the opportunity to focus our efforts on fine tuning the process and, in this way, promoting the buy-in from key stakeholders. In the end, we should keep in mind coping with all the risks identified in the FMEA.

5.5 Control phase

5.5.1 Scope

This phase of our case study will help us identify the tools needed to ensure that maintenance improvements will be sustained after the decision of top management in the plant to move on with the implementation of the project.

We must define who is responsible for collecting and reviewing the data, as well ensuring that the measurements have been integrated into the defect trees report of the plant. It is, also, necessary to standardize the WCP (World Class Performance) approach to improving processes and to quantify the improvement in the process performance between this year and the previous ones.

It is worth mentioning that clear \`knowledge management´ is critical in order to help all employees understand the real potentials of the 6 Sigma methodology and to apply the lessons learnt from the project to different functions of the plant.

5.5.2 Control plan

In order to implement ongoing measurement of the process we will periodically (frequency to be agreed with Can Lines supervisor) record all data regarding:

- Key maintenance events
- Measurement methods
- Measure obtained
- Responses to out of specification results

For this reason, we will distribute a Control Plan among the stakeholders so that whenever a deviation in the process takes place a Reaction Plan will be activated, as illustrated in Table 9. A control plan is a process management document that summarizes details for issues such as who is responsible for doing an action, what is being controlled (either input X or output Y of the process), how do we measure it (Table 7), what is the control mechanism (maintenance schedule) and what is the response plan if out of specification.

DMAIC Control Plan											
Project:			Core Team:					Date (Orig):			
Key Contact:								Date (Rev):			
Phone:								Authorized By:			Date:
Sponsor:								Signature:			
					Measurement Plan				Response Plan		
Who or Which Dept.	What must be controlled?	X or Y?	Require-ments (specs)	Ongoing Control Mechanism	Meas'ment Technique	Sample Size	Fre-quency	Who Measures?	Action	Timing	Owner

Table 9: The DMAIC Control Plan.

5.5.3 Statistical process control (SPC) charts

It would be useful to use SPC charts to monitor the performance of our maintenance activities. SPC charts are sophisticated forms of time series plot that enable us to detect either a change in process average or in process variation.

When implementing SPC charts, the arising control limits are based on the process variation and represent the area within common causes of variation will come up. Outside of this area, there will be the special causes of variation, if any, that we will have to deal with.

Figure 29 illustrates the I-MR chart for the breakdown time of CL02 which was drowned on the basis that all the data points have been collected individually.

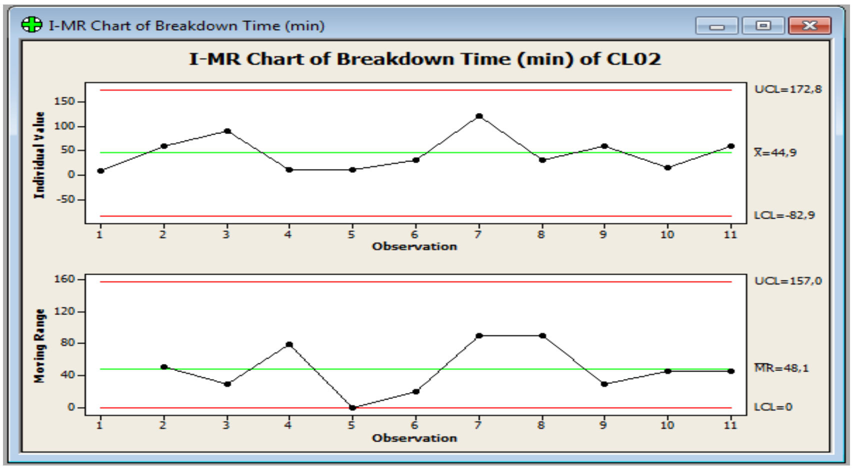


Figure 29: I-MR of breakdown time of CL02.

In this case, the process appears to be stable around about 45 minutes and it does not go outside of the control limits. Also, the same applies for process variation.

6. Conclusions

Our thesis is a practical application of 6 Sigma methodology in the evaluation of maintenance performance in CROWN Hellas Can S.A, Thessaloniki plant. It is worth mentioning that our project is the starting point of a continuous effort, to not only change the way we do maintenance but, also, the way we manage our operations since 6 Sigma is a philosophy of life.

During the implementation of the DMAIC approach, it became obvious that a 6 Sigma project needs resources and top management commitment. Although, support from top management is critical, the role of line management employees is vital, too. For this reason, training on World Class Performance concepts needs to be provided as well as appropriate visual management has to take place e.g. display boards indicating can lines defects, etc. in order to encourage employees' involvement and participation.

The most difficult part is (and will be) having the commitment to the project been spread all over the organization. In this way, we will succeed in sharing the knowledge gained from the project and in eliminating the waste in our operations.

Sometimes, it is possible for a Green Belt trainee to feel like a `lonely rider´ when he returns to the plant wishing to generate financial returns through successful projects. However, whilst there may be a significant amount of `push´ created by a newly trained Green Belt employee, it is important to create a `pull´ for Six Sigma led by the senior management. It is suggested that a meeting takes place prior to high season in order to present the potentials of the method to the shift leaders based on the findings of this thesis.

According to our experience, both the Define and Measure phases are being proved to be the most demanding. For instance, our project could be held at the Define phase for a couple of reasons such as either unclear problem statement and project objectives or low potential returns. As far as the Measure phase is concerned, the problem has been found to lie in the way the breakdown time is being measured in addition to convincing people of recording all the occurrences of defects. As a result of the previously mentioned limitations came up the small sample sizes thus affecting the Normality of data since the values tend to group in exactly the same number.

The statistical processing of data revealed that a relationship does exist between number of defects and total breakdown time and that 76.4% of defects are related to maintenance practices and wear issues. These, may, mean that we should reassess the way we implement preventive maintenance and focus our efforts on the increasing use of CMMS application. This can happen if, for instance, we produce both work orders and job guidelines of improvement type during the implementation of the Improve and Control phases.

Another interesting aspect of the data is the fact that 7.3% of causes of defects are assigned to employee skills. This is quite controversial since it is not easy to distinguish if a defect is related to a badly maintained machine and is linked to a number of issues like lack of training, limited resources, etc.

As far as the implementation of preventive maintenance policy is concerned, we consider it to be a highly challenging goal. This is happening due to the fact that we need to provide good feedback to the system; otherwise, maintenance reporting is neither able to support alternative maintenance strategies nor appropriate to support capital expenditures, e.g. new machinery; however it is essential to be able to produce good reports since maintenance is a service function for production and it has the potential to provide an organization with competitive advantage thus making influence to the plant performance.

This, also, applies to the case of CROWN Hellas Can since maintenance reporting is only limited to the financial aspect. We come up to the conclusion that CMMS integration in our daily operations is part of a Total Quality Management (TQM) approach. This is due to the fact that we have to overcome the existing organizational culture and persuade all personnel that the added value from its implementation is worth fighting for. Also, the Planner module, which is the preventive `dimension´ of our CMMS, is based on the Plan, Do, Check, Act (PDCA) Deming’s cycle.

Finally, it is well understood that a lot of the concepts from the relevant literature have application to our case study and that the establishment of valid preventive maintenance based on the statistical processing of data will allow the improvement of plant performance.

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Appendix A > Defect Trees

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D e t a i l s   E q u i p m e n t   D e f e c t s

Equipment Code		Nb of occurrences
643CN01	Food Canlines Line 01	

- MECH - Μηχανολογικό 3
  - WEAR - Φθορά 2
    - WEAR - Φθορά 2
      - REPL - Αντικατάσταση 2
  - MAINT - Πρόβλημα συντήρησης 1
    - WEAR - Φθορά 1
      - REPL - Αντικατάσταση 1
- QUAL - Ποιοτικό πρόβλημα 2
  - MAINT - Πρόβλημα συντήρησης 1
    - TOOLD - Υπερβολικά παλιό 1
      - EMERC - Αποκατάσταση έκτακτης ανάγκης 1
  - WEAR - Φθορά 1
    - SETT - Λανθασμένη ρύθμιση μηχανής 1
      - REPL - Αντικατάσταση 1
- TOOL - Εργαλείο 2
  - CONS - Πρόβλημα κατασκευής 1
    - MAT - Λάθος υλικό 1
      - EMERC - Αποκατάσταση έκτακτης ανάγκης 1
  - MAINT - Πρόβλημα συντήρησης 1
    - WEAR - Φθορά 1
      - REPL - Αντικατάσταση 1

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Defect tree for Can Line 01

D e t a i l s   E q u i p m e n t   D e f e c t s

Equipment Code		Nb of occurrences
643CN02	Food Canlines Line 02	
MECH - Μηχανολογικό	: No Symptom	3
WEAR - Φθορά		2
TOOLD - Υπερβολικά παλιό		1
REPL - Αντικατάσταση		1
WEAR - Φθορά		1
EMERC - Αποκατάσταση έκτακτης ανάγκης		1
MAINT - Πρόβλημα συντήρησης		1
SETT - Λανθασμένη ρύθμιση μηχανής		1
RESE - Επαναρύθμιση		1
TOOL - Εργαλείο	: No Symptom	3
OVERL - Υπερφόρτωση		3
SETT - Λανθασμένη ρύθμιση μηχανής		2
REPL - Αντικατάσταση		2
WEAR - Φθορά		1
CNEW - Αλλαγή σε νέο		1
PNEU - Πνευματικό	: No Symptom	2
WEAR - Φθορά		2
TOOLD - Υπερβολικά παλιό		1
REPL - Αντικατάσταση		1
WEAR - Φθορά		1
REPL - Αντικατάσταση		1
QUAL - Ποιοτικό πρόβλημα	: No Symptom	2
CONS - Πρόβλημα κατασκευής		1
MAT - Λάθος υλικό		1
REPL - Αντικατάσταση		1
MAINT - Πρόβλημα συντήρησης		1
SETT - Λανθασμένη ρύθμιση μηχανής		1
RESE - Επαναρύθμιση		1
ELEC - Ηλεκτρολογικό	: No Symptom	1
MAINT - Πρόβλημα συντήρησης		1
SKILLS - Επιδεξιότητες εργαζόμενου		1
RESE - Επαναρύθμιση		1

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Defect tree for Can Line 02

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D e t a i l s   E q u i p m e n t   D e f e c t s

Equipment Code		Nb of occurrences
643CN05	Food Canlines Line 05	

- QUAL - Ποιοτικό πρόβλημα 5
  - MAINT - Πρόβλημα συντήρησης 2
    - SETT - Λανθασμένη ρύθμιση μηχανής 1
      - REPL - Αντικατάσταση 1
    - TOOLD - Υπερβολικά παλιό 1
      - EMERC - Αποκατάσταση έκτακτης ανάγκης 1
  - WEAR - Φθορά 2
    - TOOLD - Υπερβολικά παλιό 1
      - REPL - Αντικατάσταση 1
    - WEAR - Φθορά 1
      - REPL - Αντικατάσταση 1
  - CONS - Πρόβλημα κατασκευής 1
    - MAT - Λάθος υλικό 1
      - REPL - Αντικατάσταση 1
- TOOL - Εργαλείο 5
  - MAINT - Πρόβλημα συντήρησης 2
    - WEAR - Φθορά 2
      - REPL - Αντικατάσταση 2
  - WEAR - Φθορά 2
    - MAT - Λάθος υλικό 1
      - EMERC - Αποκατάσταση έκτακτης ανάγκης 1
    - WEAR - Φθορά 1
      - REPL - Αντικατάσταση 1
  - OVERL - Υπερφόρτωση 1
    - SKILLS - Επιδεξιότητες εργαζόμενου 1
      - REPL - Αντικατάσταση 1
- MECH - Μηχανολογικό 4
  - WEAR - Φθορά 2
    - SETT - Λανθασμένη ρύθμιση μηχανής 1
      - REPL - Αντικατάσταση 1
    - WEAR - Φθορά 1
      - CNEW - Αλλαγή σε νέο 1

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Defect tree for Can Line 05

Equipment Code	Nb of occurrences
MAINT - Πρόβλημα συντήρησης	1
WEAR - Φθορά	1
REPL - Αντικατάσταση	1
OVERL - Υπερφόρτωση	1
WEAR - Φθορά	1
REPL - Αντικατάσταση	1
ELEC - Ηλεκτρολογικό	2
: No Symptom	
MAINT - Πρόβλημα συντήρησης	2
SETT - Λανθασμένη ρύθμιση μηχανής	2
CNEW - Αλλαγή σε νέο	1
EMERC - Αποκατάσταση έκτακτης ανάγκης	1
HYDR - Υδραυλικό	2
: No Symptom	
LEAK - Διαρροές ουσιών	1
WEAR - Φθορά	1
REPL - Αντικατάσταση	1
TEMP - Υπερθέρμανση	1
WEAR - Φθορά	1
REPL - Αντικατάσταση	1

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Defect tree for Can Line 05 (cont.)

D e t a i l s   E q u i p m e n t   D e f e c t s

Equipment Code		Nb of occurrences
643CN06	Food Canlines Line 06	

- QUAL - Ποιοτικό πρόβλημα 9
  - MAINT - Πρόβλημα συντήρησης 7
    - SETT - Λανθασμένη ρύθμιση μηχανής 5
      - MODI - Τροποποίηση 2
      - RESE - Επαναρύθμιση 2
      - REPL - Αντικατάσταση 1
    - CMAT - Αλλαγή υλικού 1
      - EMERC - Αποκατάσταση έκτακτης ανάγκης 1
    - WEAR - Φθορά 1
      - REPL - Αντικατάσταση 1
  - CONS - Πρόβλημα κατασκευής 1
    - SETT - Λανθασμένη ρύθμιση μηχανής 1
      - REPL - Αντικατάσταση 1
  - LEAK - Διαρροές ουσιών 1
    - SETT - Λανθασμένη ρύθμιση μηχανής 1
      - REPL - Αντικατάσταση 1
- TOOL - Εργαλείο 4
  - MAINT - Πρόβλημα συντήρησης 2
    - WEAR - Φθορά 2
      - CNEW - Αλλαγή σε νέο 1
      - REPL - Αντικατάσταση 1
  - OVERL - Υπερφόρτωση 1
    - WEAR - Φθορά 1
      - EMERC - Αποκατάσταση έκτακτης ανάγκης 1
  - WEAR - Φθορά 1
    - WEAR - Φθορά 1
      - EMERC - Αποκατάσταση έκτακτης ανάγκης 1
- PNEU - Πνευματικό 3
  - WEAR - Φθορά 2
    - TOOLD - Υπερβολικά παλιό 1
      - CNEW - Αλλαγή σε νέο 1
    - WEAR - Φθορά 1

Defect tree for Can Line 06

Equipment Code	Nb of occurrences
CNEW - Αλλαγή σε νέο	1
MAINT - Πρόβλημα συντήρησης	1
SETT - Λανθασμένη ρύθμιση μηχανής	1
RESE - Επαναρύθμιση	1
HYDR - Υδραυλικό	1
MAINT - Πρόβλημα συντήρησης	1
POLLU - Μόλυνση	1
EMERC - Αποκατάσταση έκτακτης ανάγκης	1
MECH - Μηχανολογικό	1
MAINT - Πρόβλημα συντήρησης	1
SKILLS - Επιδεξιότητες εργαζόμενου	1
EMERC - Αποκατάσταση έκτακτης ανάγκης	1
OOSP - Εκτός προδιαγραφών	1
WEAR - Φθορά	1
SKILLS - Επιδεξιότητες εργαζόμενου	1
CNEW - Αλλαγή σε νέο	1

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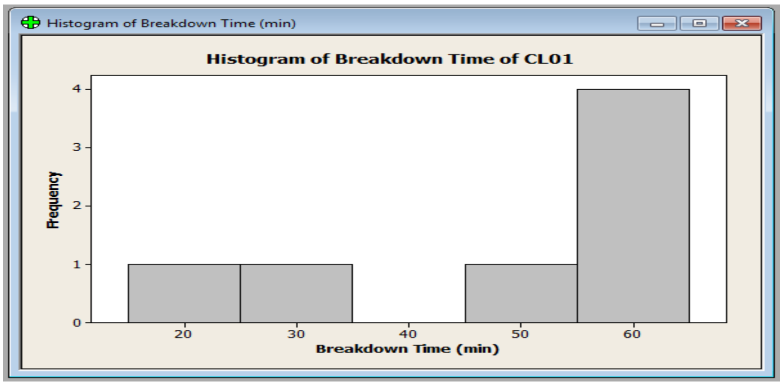
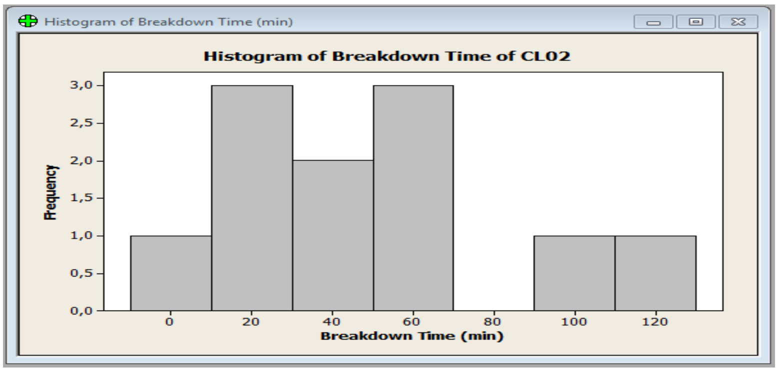
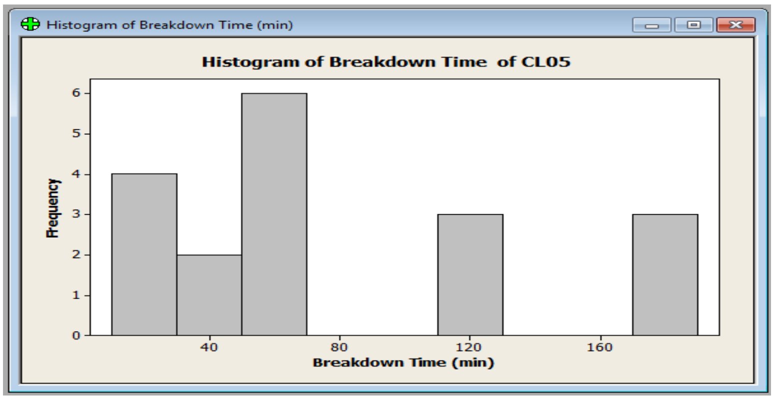
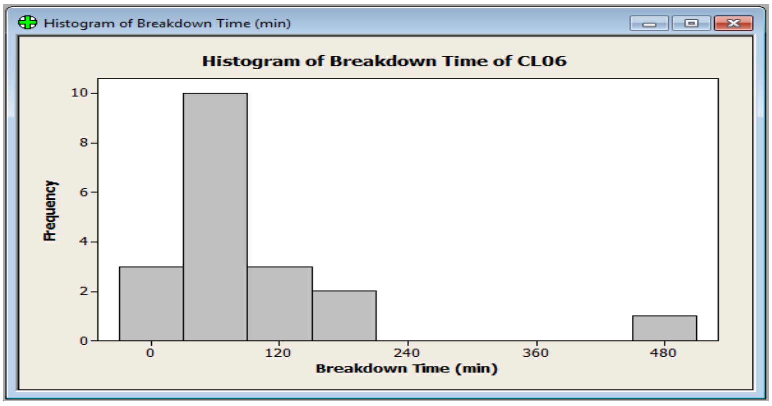
Defect tree for Can Line 06 (cont.)

Appendix B > Histograms

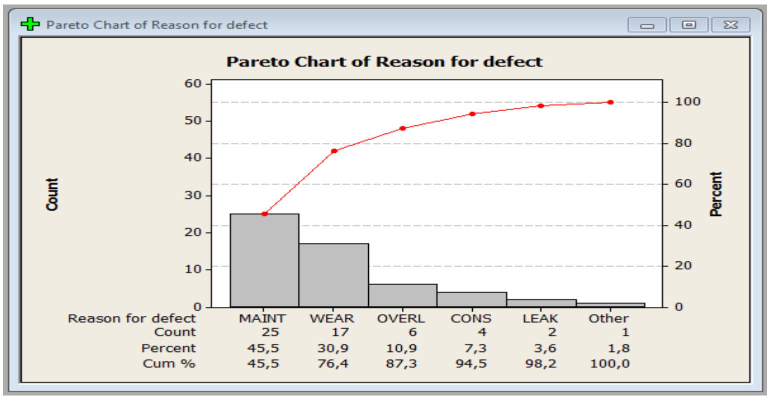


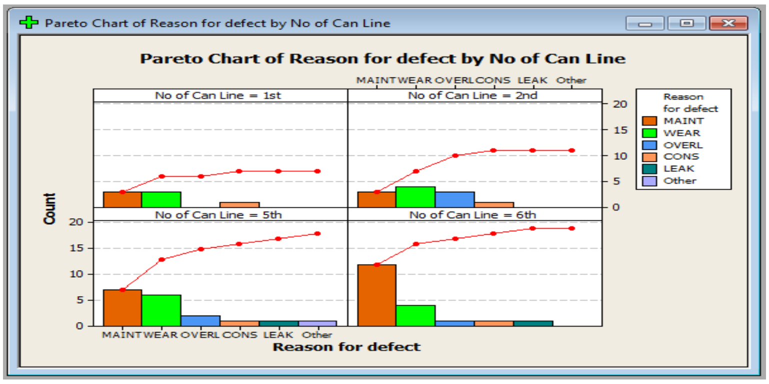


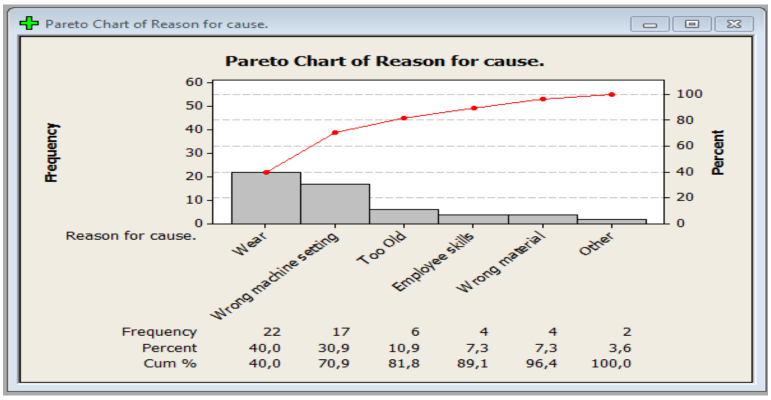


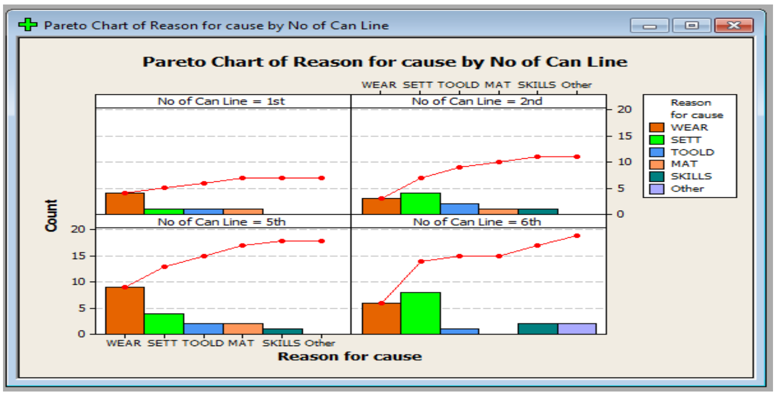


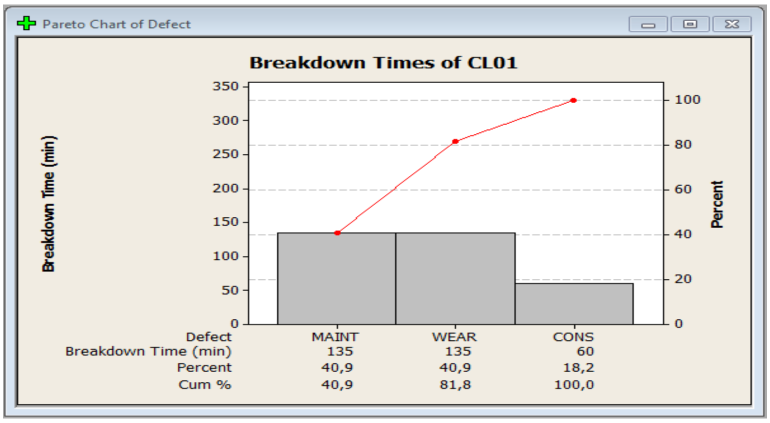
Appendix C > Pareto Charts

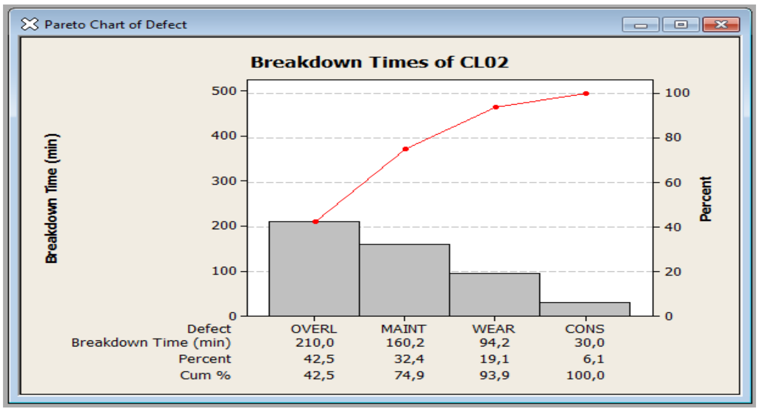


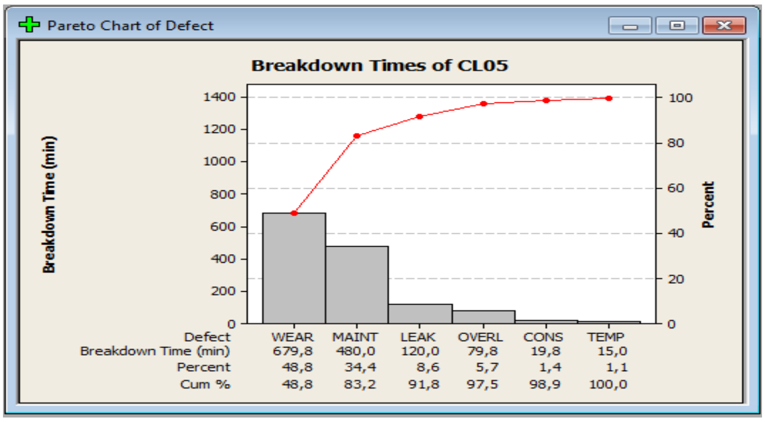


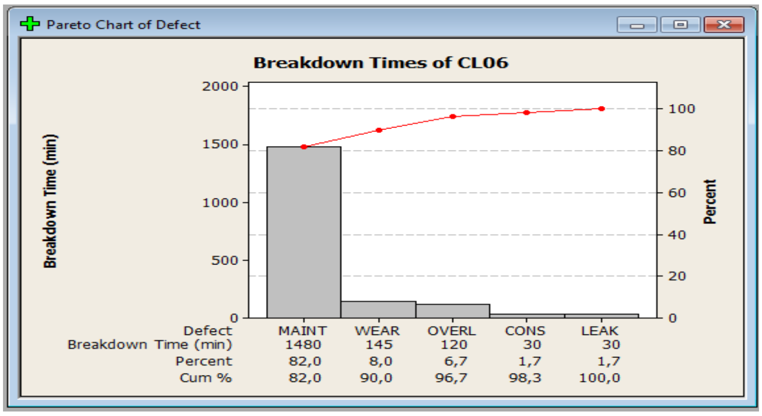





Pareto Chart of Defect
Breakdown Times of CL01
Breakdown Time (min)
Percent
Defect MAINT WEAR CONS
Breakdown Time (min) 135 135 60
Percent 40,9 40,9 18,2
Cum % 40,9 81,8 100,0


Pareto Chart of Defect
Breakdown Times of CL02
Breakdown Time (min)
Percent
Defect OVERL MAINT WEAR CONS
Breakdown Time (min) 210,0 160,2 94,2 30,0
Percent 42,5 32,4 19,1 6,1
Cum % 42,5 74,9 93,9 100,0


Pareto Chart of Defect
Breakdown Times of CL05
Breakdown Time (min)
Percent
Defect WEAR MAINT LEAK OVERL CONS TEMP
Breakdown Time (min) 679,8 480,0 120,0 79,8 19,8 15,0
Percent 48,8 34,4 8,6 5,7 1,4 1,1
Cum % 48,8 83,2 91,8 97,5 98,9 100,0


Pareto Chart of Defect
Breakdown Times of CL06
Breakdown Time (min)
Percent
Defect MAINT WEAR OVERL CONS LEAK
Breakdown Time (min) 1480 145 120 30 30
Percent 82,0 8,0 6,7 1,7 1,7
Cum % 82,0 90,0 96,7 98,3 100,0

Appendix D > Annual Maintenance of CL02

Work Order In History

CROWN
Brand-Building Packaging™

WO#:	**935**				
Equipment:	643CN02	Food Canlines Line 02			
System:	643				
Zone:	FOOD				
Function:	CAN ASSEMB				
Cost Center:	643446				
Job ID:	JOB000205	Annual Maintenance CL02 - ΕΤΗΣΙΑ ΣΥΝΤΗΡΗΣΗ ΓΡΑΜΜΗΣ No2			
Req. Entity:	643CNF	**Action Entity:**	643CNF		
Supervisor:		**Eqp. serial #:**		**Priority:**	NEXTMAIN
Work Permit:		**Criticality:**	0- Normal		
Job Type:	OVHL	Γενική			
Job Class:	AD	Ρυθμίσεις Μηχανής			
Contract:		**JR#:**	JR00000168	**Parent WO:**	
Project:		**Plan#:**		**Shift:**	0

Schedule date:	14/10/2011	**Target Date:**	14/10/2011	**Job Duration:**	1 Jour
Start Date:	14/10/2011 14:19:14	**End Date:**	02/12/2011 14:14:48	**Actual Time:**	1 176.00 Hrs

- Notes -

ZAPARTASZ - 02-12-2011 14:29:42
Εβδομάδα 45: Είχαν τελειώσει όλα, εκτός από το conveyor του sidestripe.
Την συγκεκριμένη εβδομάδα χρεώθηκαν:
Κοντογιάννης: 16 ώρες
Σιδηρόπουλος: 28 ώρες
Ταμπακάκης: 22 ώρες
ZAPARTASZ - 30-11-2011 12:26:00
ΈΝΑΡΞΗ ΣΥΝΤΗΡΗΣΗΣ: 06/10/2011
ΟΛΟΚΛΗΡΩΣΗ ΣΥΝΤΗΡΗΣΗΣ & ΔΟΚΙΜΕΣ: 14/11/2011
ZAPARTASZ - 24-11-2011 08:48:22
SOUDRONIC (Π.Σιδηρόπουλος & Χ. Ταμπακάκης)
1. Κατασκευή νέου conveyor εξόδου (Soudronic-Oven)
2. Τοποθέτηση roll-coater
FLANGER (Πριμεράκης Θ.)
1. Αντικατάσταση ρουλεμάν
2. Αντικατάσταση 2 άξονες
3. Γρασσάρισμα
BEADER (Φωτιάδης Μ.)
1. Γυάλισμα ράουλα
2. Συμπλήρωμα (15-20λτ) λάδια
3. Πλύσιμο ανταλλακτικών
4. Αντικατάσταση 2 μικρά και 2 μεγάλα γρανάζια καδένας εισόδου
5. Αντικατάσταση 6 βρουλεμάν
BORDEN (Πριμεράκης Θ.)
1. Αντικατάσταση λάστιχα πατήματος κεφαλών
2. Γρασσάρισμα
3. Επιδιόρθωση εμβόλων συστήματος απόρριψης
ZAPARTASZ - 11-11-2011 08:24:11
OVEN (Σ. Μπιλμπέρης)
1. Καθαρισμός μπουριά
ZAPARTASZ - 11-11-2011 08:22:02
SOUDRONIC (Π. Σιδηρόπουλος & Χ. Ταμπακάκης)
1. Επισκευή όλων των κιβωτιών πλην διαμορφωτικού & κίνησης σύρματος
2. Επισκευή κόπλερ β΄φάσης
3. Καινούριος κεντρικός άξονας κίνησης & ρουλεμάν roll station. Επισκευή αντίστοιχου κόπλερ
4. Καθαρισμός & λίπανση ρουλεμάν αξόνων roll station
5. Αντικατάσταση ρουλεμάν σε όλους τους τεντωτήρες

23/01/2012 07:15:54 Page 1 of 4

6. Αντικατάσταση καδενών & ιμάντων κίνησης
7. Αντικατάσταση ελαστικών κυκλοφορίας νερού
8. Εγκατάσταση νέου κλωβού καθοδήγησης
9. Έλεγχος κόφτη σύρματος
10. Καθαρισμός & επισκευή τροχαλιών οδήγησης σύρματος

ZAPARTASZ - 11-11-2011 08:09:58

ΑΥΤΟΜΑΤΟΣ ΤΡΟΦΟΔΟΤΗΣ (Γιάννης Σιμόπουλος)

1. Έλεγχος & γενική επισκευή στα ραουλάκια & ρουλεμάν μαγν.ταινιών
2. Αντικατάσταση ορισμένου αριθμού μαγνητικών ταινιών
3. Αντικατάσταση ρουλεμάν (εντός γραναζιού) τεντωτήρα ιμάντας κίνησης A/T
4. Έλεγχος "χαλαρώματος" και 2 αξόνων ιμάντων
5. Βάψιμο εξοπλισμού

ZAPARTASZ - 11-11-2011 08:06:00

SLITTER (Γιάννης Σιμόπουλος)

1. Έλεγχος βεντουζών & λίπανση εμβόλων
2. Έλεγχος σωληνώσεων (υποπίεση)
3. Αντικατάσταση (από πλαστικό) ιμάντων μεταφοράς φύλλου
4. Ρεκτιφιέ μαχαιριών ά & β' φάσης
5. Γρασσάρισμα ρουλεμάν αξόνων
6. Αντικατάσταση γραναζιών & ρουλεμάν αξόνων μεταφοράς ά φάσης
7. Αντικατάσταση (νέα κατασκευή) καδένας μεταφοράς β΄ φάσης
8. Αντικατάσταση καδένας κίνησης ά φάσης (από κιβώτιο σε γωνιακή)
9. Γρασσάρισμα γενικό
10. Έλεγχος λαδιών

ZAPARTASZ - 11-11-2011 07:48:14

SEAMER (Δ. Στεφανίδης)

1. Αντικατάσταση 2 γρανάζια τροφοδοσίας καπακιών
2. Κατασκευή (από εμάς) άξονα συστ.μετάδ.κίνησης για τροφοδ.καπακιών
3. Αντικατάσταση (νέος τύπος) φωτοκύτταρου τροφοδοσίας καπακιών
4. Αντικατάσταση (λόγω φθορά) καδένας μεταφοράς κουτιών
5. Αντικατάσταση 12 (6 κεφαλές x 2) κωνικά ρουλεμάν
6. Αντικατάσταση 12 o-ring στα μπράτσα ραούλων
7. Αντικατάσταση 6 τσιμούχες αξόνων τσοκ
8. Αντικατάσταση σε όλους τους άξονες τσοκ: o-ring στο δαχτυλίδι, τσιμούχας και o-ring κάτω από το ρουλεμάν
9. Αντικατάσταση και στα 6 πλατό: 6 ρουλεμάν και 6 τσιμούχες
10. Επισκευή (πήραμε τα "μπόσικα") συστήματος έδρασης πλατό. Βάφτηκε το αντίστοιχο δαχτυλίδι για μεγαλύτερη αντοχή
11. Συμπλήρωση λαδιών
12. Αντικατάσταση καδένας εισόδου μεταφοράς κουτιών

ZAPARTASZ - 14-10-2011 14:16:31

PALLETIZER (Ν. Αναστασάκης & Χ. Φανάρας)

ΩΘΗΤΗΡΑΣ

1. Αλλαγή ρουλεμάν στις μπουκάλες
2. Αλλαγή τσιμούχα σε έμβολο
3. Καινούριες σφήνες στα γρανάζια του κινητήρα
4. Αλλαγή οδηγών
5. Αντικατάσταση απλών παξιμαδιών σιδηρόδρομου με ασφαλείας
6. Έλεγχος καδενών, γραναζιών καδενών, φρένου και γραναζιών φρένου

ΠΗΡΟΥΝΙΑ ΚΡΑΤΗΣΗΣ

1. Αλλαγή στις τσιμούχες εμβόλου

ΗΛΕΚΤΡΙΚΑ ΜΠΟΥΤΟΝ

1. Ελέχθηκαν και βρέθηκαν εντάξει

ΑΠΟΘΗΚΗ ΠΑΛΕΤΩΝ

1. Έλεγχος κινητήρα (στάθμη λαδιού και διαρροές)
2. Έλεγχος εμβόλων κράτησης παλετών, καδενών και γραναζιών

ΑΝΕΒΑΤΟΡΙ ΠΑΛΕΤΩΝ

1. Έλεγχος λαδιών, καδένας και τσιμούχας άξονα μεγάλου γραναζιού

ΠΛΑΤΦΟΡΜΑ ΣΤΡΩΣΗΣ

1. Αντικατάσταση 2 καδενών (5.15μ καθεμία)
2. Έλεγχος ρουλεμάν
3. Φινίρισμα σιδηρόδρομου

Να πραγματοποιηθεί η προβλεπόμενη, ετήσια συντήρηση της Γραμμής Νο2.

- Employee Feedback -

Employee	Rate	Start Date	End Date	Actual Hours
5052 - TABAKAKIS CHARALAMPOS				**Total : 135.00**
	100%	02/12/2011 14:14:00	02/12/2011 14:14:00	135.00
5104 - STEFANIDIS DIMITRIOS				**Total : 136.00**
	100%	01/12/2011 14:09:42	01/12/2011 14:09:42	136.00
5114 - FANARAS CHRISTOS				**Total : 96.00**
	100%	01/12/2011 14:10:33	01/12/2011 14:10:33	96.00
5116 - SIDIROPOULOS PAVLOS				**Total : 148.00**
	100%	01/12/2011 08:40:43	01/12/2011 08:40:43	148.00
5173 - KONTOGIANNIS ATHANASIOS				**Total : 126.00**
	100%	02/12/2011 14:14:48	02/12/2011 14:14:48	126.00
5180 - SAVVELIS KONSTANTINOS				**Total : 136.00**
	100%	01/12/2011 14:11:18	01/12/2011 14:11:18	136.00
5259 - SIMOPOULOS IOANNIS				**Total : 119.00**
	100%	01/12/2011 14:05:16	01/12/2011 14:05:16	119.00
5269 - BILBERIS SPIROS				**Total : 124.00**
	100%	01/12/2011 14:08:29	01/12/2011 14:08:29	124.00
5270 - PRIMERAKIS THOMAS				**Total : 120.00**
	100%	01/12/2011 14:09:11	01/12/2011 14:09:11	120.00
7792 - FOTIADIS MICHALIS				**Total : 124.00**
	100%	01/12/2011 14:10:10	01/12/2011 14:10:10	124.00
7918 - MOISIDIS XARALABOS				**Total : 136.00**
	100%	01/12/2011 14:07:38	01/12/2011 14:07:38	136.00
7932 - BOULTSOS NIKOLAOS				**Total : 136.00**
	100%	01/12/2011 14:06:17	01/12/2011 14:06:17	136.00
7940 - ANASTASAKIS NIKOS				**Total : 126.00**
	100%	01/12/2011 14:10:54	01/12/2011 14:10:54	126.00

- Allocated Employee -

Employee	Resource	Alloc. Date	Sched. Date
5116 SIDIROPOULOS PAVLOS	SM	14/10/2011	14/10/2011 00
5173 KONTOGIANNIS ATHANASIOS	LO	14/10/2011	14/10/2011 00
5180 SAVVELIS KONSTANTINOS	MECH	14/10/2011	14/10/2011 00
5052 TABAKAKIS CHARALAMPOS	LO	14/10/2011	14/10/2011 00
5259 SIMOPOULOS IOANNIS	LO	14/10/2011	14/10/2011 00
5269 BILBERIS SPIROS	LO	14/10/2011	14/10/2011 00
5104 STEFANIDIS DIMITRIOS	LO	14/10/2011	14/10/2011 00
5270 PRIMERAKIS THOMAS	LO	14/10/2011	14/10/2011 00
5114 FANARAS CHRISTOS	LO	14/10/2011	14/10/2011 00
7918 MOISIDIS XARALABOS	LO	14/10/2011	14/10/2011 00
7792 FOTIADIS MICHALIS	LO	14/10/2011	14/10/2011 00
7932 BOULTSOS NIKOLAOS	MECH	14/10/2011	14/10/2011 00
7940 ANASTASAKIS NIKOS	LO	14/10/2011	14/10/2011 00

- Stock -					
Item		Unit	Plan. Qty	Actual Qty	Material Cost
1125892	1/2" RENOLD CHAIN 110046	EURO	1.00	8.00	232.00
1126158	RENOLD 3/8" CHAIN NO. 110038	EURO	15.00	27.00	594.00
1758323	TOOTHED BELT 210L075	EURO	1.00	1.00	3.78
1758366	TOOTHED BELT 210L100G	EURO	1.00	1.00	4.91
1758622	TOOTHED BELT 255L100	EURO	1.00	1.00	5.49
1758825	TOOTHED BELT 300L100	EURO	1.00	1.00	6.05
1758892	TOOTHED BELT 300H100	EURO	1.00	1.00	6.63
1760642	TOOTHED BELT HTD 880-8M-30	EURO	1.00	2.00	43.80
1419639	TOOTHED BELT HTD 1440-8M-50	EURO	1.00	1.00	43.50
1200768	BAND PROTECTION L.H	EURO	1.00	1.00	30.21
1829638	VULCOLAN ROLLER Φ=41	EURO	1.00	1.00	351.67
1201269	SWIVEL BEARING REAR SIDE	EURO	1.00	1.00	258.14
1902065	DRIVER DOG 30	EURO	5.00	5.00	14.50
2029190	CLAMP PAD RUBBER80F-R-80	EURO	5.00	5.00	56.50
8680899	ΙΜΑΣ ΔΙΠΛΟΣ 300L100 X 1	EURO	1.00	1.00	50.82
8681058	ΙΜΑΣ TIMING 600L125 X 1	EURO	2.00	2.00	24.58
8681066	TOOTHED BELT HTD 960-8M-30	EURO	1.00	1.00	19.65
9073564	RENOLD CHAIN 110066	EURO	3.00	3.00	120.60
NJDEWO935	10 ΡΟΥΛΕΜΑΝ (60001-2Z, 60032Z, 6305-2Z) 8	EURO	1.00	1.00	206.80
NJDEWO935B	ΚΑΤΑΣΚΕΥΗ 2 ΤΕΜΑΧΙΩΝ ΣΦΙΓΚΤΗΡΑ ΜΕ ΠΟΛΥ	EURO	1.00	1.00	300.00
NJDEWO935C	ΚΑΤΑΣΚΕΥΗ & ΠΡΟΣΑΡΜΟΓΗ 1 ΓΡΑΝΑΖΙΟΥ 3/8'	EURO	1.00	1.00	1,400.00
NJDEWO935D	2 ΑΤΕΡΜΟΝΕΣ ΙΜΑΝΤΕΣ 15mm X 2780 ΤΥΠΟΥ	EURO	1.00	1.00	370.00
NJDEWO935E	GENERAL LEDGER AMOUNT - BOYTSOYKHS AM	EURO	1.00	1.00	1,494.12

- Resource -			
Resource	Plan. Num	Plan. Hrs	Actual Hrs
LO - Line Operator	10	0.00	1,242.00
MECH - Mechanical	2	0.00	272.00
SM - Shift Leader	1	0.00	148.00

	- Planned -	- Actual -
Hours:	0.00 Hr	1 662.00 Hrs
Labour Cost:	0.00 EUR	24 280.00 EUR
Material Cost:	0.00 EUR	5 637.75 EUR
Facility Cost:	0.00 EUR	0.00 EUR
Miscellaneous Cost:		0.00 EUR
Recovery Cost :		0.00 EUR
Total:	**0.00 EUR**	**29 917.75 EUR**

Appendix E > Project Charter Documents

CROWN
Brand-Building Packaging™

PROJECT CHARTER (FINANCE ANALYSIS)

WCP

Plant:	:	Thessaloniki
Project / Activity Title	:	Identification of critical equipment
WCP Dimension Project is aligned to	:	Maintenance
Date Project Commenced	:	01/08/2011
Estimated Date Project Completed	:	31/01/2012

Name of Team Members:	Role:
Anastasios Derveniotis	Champion
Kostas Dimitriadis	Team member
Ioannis Falkos	Team member
Anna Giailaoglou	Team member
Gabriel Tatoglou	Process Owner
Zafeirios Zapartas	Green Belt

Problem Statement:

The plant does not implement CMMS maintenance. This has an impact on both costs (labour, repair, etc.) and performance (breakdown time, etc.). The equipment effectiveness is not measured so we do not know the optimum equipment output.

Project Objectives:

We will make use of reliable KPIs to achieve:
1. Reduction of global breakdown time by 10%
2. Reduction of total number of defects by 5%

by the end of January 2012.

Milestones: End of September 2011
End of November 2011
End of January 2012

<u>To be filled by the Plant Manager:</u>

Opening Project | **Closing Project**

Initial Figures	Estimated figures at the end	Real figures

Page 1

CROWN
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PROJECT CHARTER (FINANCE ANALYSIS)

WCP

To be filled by the Finance Manager:

Opening Project - Benefits Estimated:

Concept	Eur
Reduction on breakdown time by 10%	
Reduction on total number of defects by 5%	

Closing Project

Real Benefits ($)
Minimize labour
Minimize repairs
Minimize energy
Minimize breakdown time/defects , improve Line efficiency and consequently cost per line hour.

Opening Project - Cost Estimated

Concept	$

Closing Project

Real Cost ($)

Opening Project

Total Profits Estimated ($)
Estimated benefit 3.7 keur for the period October 2011-end of January 2012

Closing Project

Real Total Profits ($)
Annually benefit 11.1 keur

Signatures:

Opening Project

Plant Manager Signature	Date
	13/10/11

Closing Project

Plant Manager Signature	Date

Opening Project

Finance Manager Signature	Date
	13/10/11

Closing Project

Finance Manager Signature	Date