CHALMERS

Premium Quality for a Mechanical Design Department

Master's Thesis in the Master's programme Product Development

MARTIN FÄGERLIND

GUILLEM ROFÍN-SERRÀ

Department of Product and Production Development
Division of Product Development
CHALMERS UNIVERSITY OF TECHNOLOGY
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Abstract

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This Thesis has been carried out in a market which is expected to grow rapidly in the next decade. Because of this, actors in the market like Alpha want to strengthen their business position through refining the quality of their products and processes. One of the internal targets of MD, a mechanical design department within Alpha, referred to "*premium product quality parameters*" although these were not defined. Hence, this Thesis intends to contribute in the definition and understanding that Alpha has of the concept of *Premium Quality*. The data used comes from two sources; on one side, a literature research about the concepts of premium, quality, quality management schools and knowledge management. On the other side, an internal research collecting opinions from the different departments involved in the development of mechanical components, with the objective of highlighting problems and suggesting solutions for getting closer to a "*premium quality*". BPMN diagrams, DSMs, the KJ method and Fishbone diagrams have been used for analysing the collected information. The findings have been organised through Garvin's five approaches to quality and the 4 P's suggested in the Toyota Way. Thus, this Thesis is delivering an interpretation of the concepts of Premium and Quality, a definition of *Premium Quality* tailored for MD and a set of recommendations for MD, such as a suggestion of indicators to be used in the internal targets and indications of what interdepartmental information flows should be revised.

Keywords

Garvin, Toyota Way, Total Quality Management, Knowledge Management, Organisational Learning, Lean Product Development

Sammanfattning

Premium Quality för en mekanisk utvecklingsavdelning

Examensarbete inom Masterprogrammet Produktutveckling

MARTIN FÄGERLIND

GUILLEM ROFÍN-SERRÀ

Institutionen för Produkt- och Produktionsutveckling

Avdelningen för Produktutveckling

Chalmers Tekniska Högskola

Det här examensarbetet har utförts inom en marknad som förväntas expandera med ökande hastighet det kommande decenniet. Aktörer på marknaden, så som Alpha, vill därför stärka sina positioner genom förbättrad intern kvalitet med avseende på både produkter och processer. Inom MD som är avdelningen för mekanisk design inom Alpha, refererrar ett av de interna strategiska målen till *”premium product quality parameters”* samtidigt som parametrarnas definition utelämnas. Detta examensarbete avser att bidra till definitionen och en utökad förståelse av begreppet *Premium Quality* inom Alpha. Examensarbetet baseras på två primära fundament, å ena sidan ett teoretiskt ramverk som omfattar koncepten premium, quality, Total Quality Management och Knowledge Management. Å andra sidan, en intern undersökning där åsikter och uppfattningar från olika avdelningar inblandade i utvecklingen av mekaniska komponenter, med avsikten att belysa problem och förbättringsförslag för att närma sig ”premium quality”. BPMN diagram, DSMs, KJ-metoden och fiskbensdiagram har implementerats för att analysera den insamlade informationen. Resultaten har organiserats i enligthet med Garvins fem ansatser till kvalitet och Toyotas 4 P. Detta examensarbete erbjuder därför en tolkning av premium och kvalitet som koncept, en definition av *Premium Quality* anpassad för MD samt ett antal rekommendationer för MD, till exempel förslag till lämpliga indikatorer för att följa upp strategiska mål samt indikationer på vilka informationsflöden mellan avdelningar som kräver ytterligare granskning.

Nyckelord

Garvin, Toyota way, Total Qualty Management, Knowledge management, Organisational Learning, Lean product development

Preface

The Mechanical Design department of a company, referred to along this report as Alpha, intended to achieve a new point of view about Quality, as well as updating the ways of working and thinking deployed by its Quality Drivers.

Underlining the premises of a wide and fresh point of view, these Quality Drivers commissioned the execution of this Master's Thesis to two students of the Product Development programme at Chalmers Tekniska Högskola (Göteborg). Together with a literature review, the assignment would involve contacting people from many different departments and locations, in order to improve the current state with the principles and tools acquired from the literature.

We would like to thank Alpha for providing us with the opportunity to carry out our Master's Thesis within the department of Mechanical Design. We show our most sincere gratitude to all the people who, either participating in the interviews or in other ways collaborated with us along the course of this Master's Thesis.

We give special thanks to all our fellow workmates in Mechanical Design for their daily support and encouragement in our efforts.

We are deeply grateful to our supervisors, both in Alpha and Chalmers for their feedback and guidance in our work.

And last but no least, we want to thank our families and friends, who have supported us during all these months.

Göteborg, August 2010

Martin Fägerlind

Guillem Rofín-Serrà

"Bitterness of low quality is worse than the sweetness of low price"

Benjamin Franklin

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Acronyms and Terminology

CIC	Continuous Improvement Council
BoM	Bill of Materials
BPMI	Business Process Management Initiative
BPMN	Business Process Modelling Notation
CAD	Computer Aided Design
CoPQ	Cost of Poor Quality
DICM	Direct Input from Customer Meeting
DMAIC	Design-Measure-Analyse-Improve-Control
DSM	Design Structure Matrix
HoQ	House of Quality
LaPP	Learning about Product and Process
LL	Lessons Learned
LPD	Lean Product Development
OD	Operational Development
OPM	Operational Product Management
PDM	Product Data Management
PDSA	Plan-Do-Study-Act
PDU	Product Design Unit
PPQ	Premium Price Quality
PQ	Premium Quality
QFD	Quality Function Deployment
RCA	Root Cause Analysis
TDCL	Technical Design Checklist
TQM	Total Quality Management
TR	Trouble Report
TW	Toyota Way

Alpha departments and stakeholders involved in the study

Cs	Customers
I&V	Integration and Verification: manage and perform verification and testing activities at the end of development.
MD	Mechanical Design department
MkD	Marketing Department: each of the regions in which the world is divided in terms of marketing and customer handling.
MQ	Master and Quality: secure the activity at the assembly lines and handle the manufacturing responsibilities amongst the different production sites.

P	Production: Alpha assembly lines
PE	Production Engineering: arrange the layout of the assembly line for the product in issue
PLM	Product Line Maintenance: responsible for customer support management and operational product management.
PM	Product Management: responsible for product roadmaps and market requirements. It is constituted by Strategic Product Managers, in opposition to the operational product managers, included in PLM
PSM	Product Sourcing Management: supplier relation management during and within the project scope.
S	Suppliers: outsourced companies delivering mechanical components
SD	System Design: system management of the MD devices.
SQ	Supplier Quality: assure the quality level of the components developed and received from the suppliers.
SS	Strategic Sourcing: supplier ownership and primary interface between sourcing and supply.

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1 Introduction

1.1 Background about Premium Quality

The market in which Alpha acts is supposed to rapidly expand during the next ten years. This supposes a great business opportunity, and the actors in the market want to be ready for it. Under these circumstances, one of the key issues for a successful market performance is the quality of the products.

Failures in product quality may cause extremely big aftermarket and the maintenance expenses, which can become unaffordable because of the magnitude of the figures that are managed; besides, the brand reliability and customer confidence could become affected leading to lost sales. Altogether, these conform what is identified in the literature as Cost of Poor Quality (CoPQ) (Bergman & Klefsjö, 2010). Today Alpha recognises both product and service quality as being one of the most important aspects to deal with in order to assure the current and future position in the market (Interviewee 16, 12th February. 2010).

In this framework, the concept of "*Premium Quality*" was pronounced by some manager in Alpha, not as a slogan to be shown to the customer, but as an internal leitmotif instead.

Each of the organisational levels within Alpha is driven by its own set of strategies and targets, gathered in a *Scorecard*, which monitors and evaluates the fulfilment of the targets. One of the targets for MD in 2010 talked about "*Premium Product Quality Parameters*", but neither the Quality drivers of the department, nor the line managers knew what it meant. Because of this lack of understanding, they had not a clear idea of what was expected from them in order to work towards a *Premium Quality*.

1.2 Problem Definition

The problem faced in this Thesis is defined through the following aspects.

1.2.1 Purpose

The main purpose of this Master's Thesis is to contribute in the definition and understanding that Alpha has of the concept of Premium Quality, becoming thus the first step of a chain of events for fulfilling this concept later on.

In parallel, this Thesis is intended to provide the authors with the possibility of applying the knowledge acquired along the Master's Programme of Product Development, and also with an overview of how a Development department is working in today's industry.

1.2.2 Objectives

The main purpose of this Thesis in concretised by the following objectives:

- Adapt an interpretation of the concept of Premium Quality for the Mechanical Design department at Alpha, to be used as a framework for future works related to quality improvement.
- Using the perspective provided by the new framework, contribute in increasing the quality performance of the organisation. This will be done through the identification of problematic aspects, the proposition of corresponding solutions within the working area of the Mechanical Design department and the suggestion of parameters to be used for monitoring the performance of the improvements achieved.

1.2.3 Scope

- Prioritise the tasks in which the MD department is involved.
- Work from an information and knowledge flow approach to the issue.
- Work towards a closed loop of knowledge inside MD.
- Pay special attention to the inter-departmental relations selected by the Alpha supervisors in which MD is involved: *MD-Product Management*; *MD – Production*, *MD – Suppliers*, *MD – Integration and Verification* and *MD-MD*.

1.2.4 Deliverables

- Definition of the concepts of Premium and Quality
- Suggestion of understanding of the concept of "Premium Quality"
- Representation of certain aspects of the current state of Alpha, in terms of processes, interdepartmental relations and mapped opinions to be used as communication tools in later analysis in-house Alpha.
- Description of problems whose overcoming appears relevant for achieving Premium Quality
- Recommendations for future work and ideas to include in the targets of the MD Scorecard for the next years

1.3 Report Outline

The following section, Methodology Description, presents and explains in twelve pages the different methods used all along the Thesis, grouped according to their purposes. Their implementation has allowed the possibility of reaching the rest of the contents of the report. Chapter 3, the, Theoretical Framework, dedicates eighteen pages to a set of theoretical concepts gathered from the literature review. They are required for explaining and relating the findings from the research performed at Alpha.

The results of the research and the analysis are presented in Chapter 4, Symptoms and Treatments. It exposes the main deliverables of the Thesis, like the interpretation of the concept of Premium Quality, two process diagrams and the set of symptoms detected which hinder the adoption of Premium Quality, and their correspondent treatments. The specific recommendations for the Mechanical Design department are gathered in section 4.6. Only one of these treatments, the LaPP process (Section 4.5) has been developed enough for being considered as an improvement suggestion; it is completely presented in Appendix B.

Finally, Chapter 5, gathers in three pages the Conclusions about the reaching of the objectives, followed by a general Discussion about the Thesis in Chapter 6.

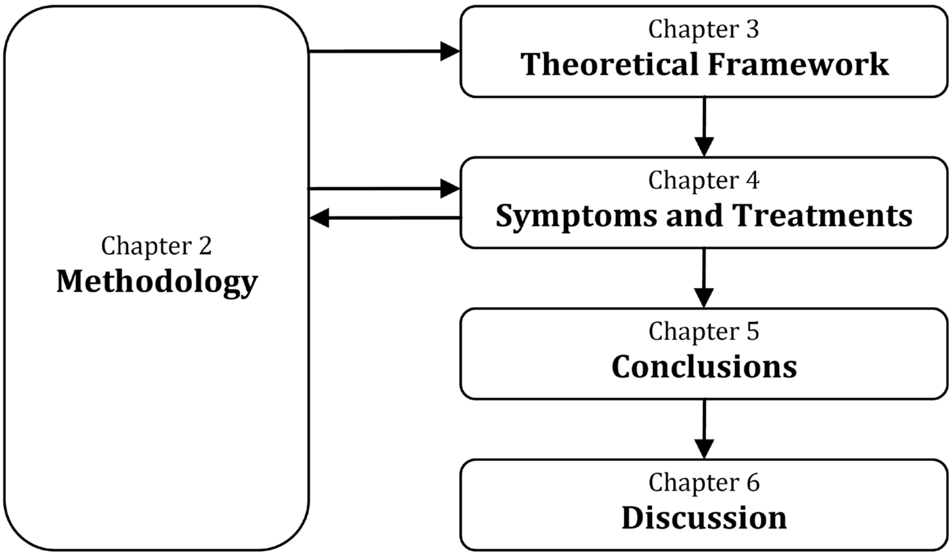

Figure 1: Relations between the chapters that complete the report.

1.3.1 For Faster Reading

- Figure 2 in page 5 offers an overview of the research approach deployed along the Thesis.
- Section 3.9 puts together the most important theoretical concepts.
- Section 4.6 lists the recommendations for MD extracted from this Thesis.
- Appendix B presents the most developed improvement suggestion, the LaPP process.

2 Methodology Description

This chapter is divided into seven main sections; *Research Design, Literature Review, Data Collection, Data Analysis, Information Analysis, Problem Solving* and *Reflections*. The chapter describes what methods were used during the execution of this Thesis and for what purpose they were chosen.

2.1 Research Design

Every research project makes use of some kind of research design, either it is carefully conducted or randomly put together. A research design can be though of as a blueprint directing the research project through the phases of data collection, analysis and interpretation of observations, each of which requires their own particular methods (Nachmias & Nachmias, 1992 cited in Yin, 2009). This blueprint is thus a logical plan devised to assure that the research objectives are addressed by the collected data and that relevant conclusions can be drawn. (Yin, 2009)

As stated in Section 1.2, this Thesis aims at reaching the objectives of highlighting problems which hinders Alpha in getting closer to the concept of Premium Quality, and to suggest solutions applicable within the MD working area (Section 1.2.2). These objectives should be reached within the scope defined in Section 1.2.3, and produce the set of deliverables stated in Section 1.2.4.

Considering this problem definition, a research design was developed and deployed according to Figure 2. It reveals that the research is based on three fundamental cornerstones; Literature Review, Primary Research and Secondary Research. The Literature Review was carried out in order to find suitable methods for collecting and analysing data and information and to build the theoretical framework.

Interviews (Section 2.3.1.1) were selected as the main tool for collecting the primary data. Secondary sources (Section 2.3.2) were also investigated and served as a complement to the collected primary data. Figure 2 shows what specific methods where applied during the *Data Analysis* stage (Section 2.4), from which the first group of deliverables was generated. These deliverables followed different paths through the subsequent stages of *Information Analysis* and *Problem Solving*, for being finally combined in a *Brainstorming/Synthesis* activity from which the final set of deliverables was generated.

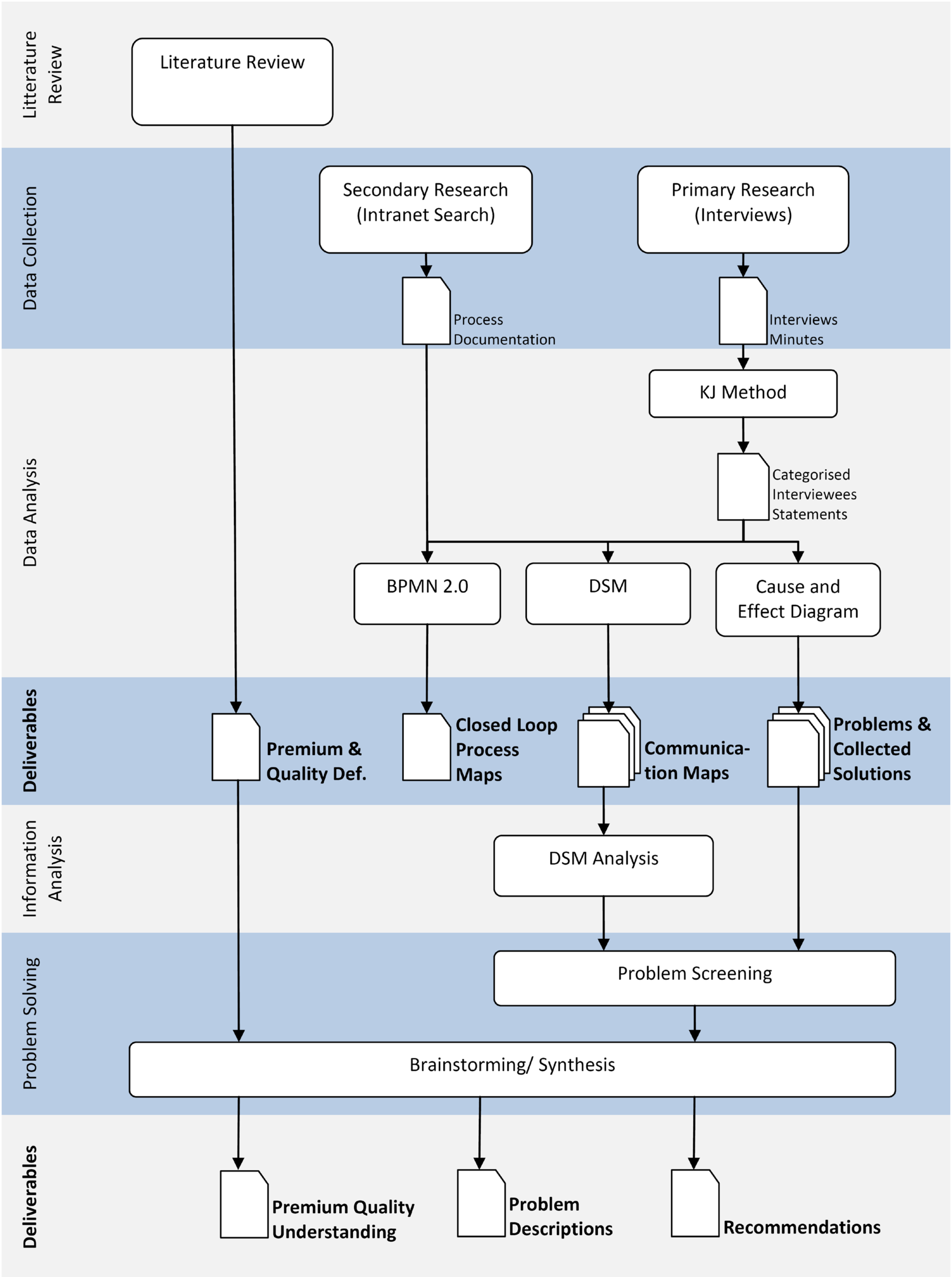

Figure 2: Research approach and deliverables.

2.2 Literature Review

Before the start of this Thesis, the authors were already familiar with the fields of Mechanical Engineering and Product Development. However, it was needed to review additional literature in order to select appropriate methods for collecting and analysing both data and information and for building the necessary Theoretical Framework. *Research Design* was investigated, for complementing the team's knowledge in data collection and analysis. Further literature was reviewed about areas like *Total Quality Management*, *the Toyota Way*, *Lean Product Development* and *Knowledge Management*[1].

During the literature review, scorecards were created in order to summarise and present the relevant information extracted from the books and articles.

2.3 Data Collection

For reaching the objectives of this Thesis (Section 1.2.2), it was necessary to collect data from both primary and secondary sources[2].

2.3.1 Primary Data

This Master's Thesis is based on a qualitative research approach (Rugg & Petre, 2006), in which interviews were chosen as the main procedure for collecting primary data. This approach was chosen because the objectives of this Thesis primarily aim at discovering problematic areas susceptible for improvement. According to McQuarrie (2006) exploratory and qualitative research techniques are preferable when the goal is discovery; to find out new characteristics and opinions existing within a population. This notion is shared by May (2002), who states that qualitative approaches are typically used in order *to "discover or develop new concepts rather than imposing preconceived categories on the people and events they observe"*.

2.3.1.1 Interviews

The primary data collection was divided into two rounds of interviews. The first round aimed at describing the current state of communication and information exchange between in-house Alpha departments on an overview level. The second round of interviews aimed at a deeper level of understanding and a more thorough analysis of the communication and information sharing. The scope of the second round covered both internal Alpha departments but also external stakeholders, such as customers and suppliers.

Conducting interviews is one of the most common approaches to qualitative research, and has almost become the standard for carrying out this type of research (May, 2002). Rugg & Petre (2006) state three core characteristics which distinguish interviews from other types of communications: two or more people *interact* with each other; it is performed in *real time* and carried out in *natural language*.

[1] See the References section for a complete list of sources.

[2] Data can generally be divided into two types; primary and secondary data. *Primary data* is collected with the purpose of supporting a specific research project. In contrast, *secondary data* is collected by someone else, for some other purpose, but is still valid for the research project at hand. (McQuarrie, 2006)

Furthermore it is common to distinguish between *un-structured, semi-structured* and *structured* interviews. In *un-structured* interviews the structure and questions are decided during the interview; the interview takes form as it happens. *Structured* interviews can almost be compared to a spoken *questionnaire*, since a pre-determined list of topics and questions is used during the execution of the interview (Rugg & Petre, 2006).

Semi-structured is thus what it sounds like; something between structured and un-structured interviews. This was the approach selected for designing the interview guides (Section 2.3.1.3), since they provide the flexibility needed for dynamically exploring each of the topics, at the same time as they assure a certain degree of consistency among the interviews.

2.3.1.2 Sampling

In this Thesis the procedure of selecting the appropriate interviewees was based on a *judgement sample* approach (McQuarrie, 2006).

The interviewees for the first round were chosen in collaboration with the Alpha supervisors, who provided a contact list of representatives from the departments of interest. In the second round, interviewees were identified and selected along the way. A small network of contacts had been built from the first round of interviews which was further extended during the course of the second round; interviewees were asked to provide further contact people which could be of interest along the research. Both managers and designers were represented among the interviewees of both rounds[3].

The use of judgement sampling is motivated by the purpose of qualitative research, which aims at identifying a set of elements, or *qualities*, in the samples which are also present within the larger population (McQuarrie, 2006). This type of inference is known as *identification generalisations*, and place relatively low requirements on the sampling procedure, rendering judgement sampling an adequate method (McQuarrie, 2006). The use of judgement sampling is further supported by the often small sample sizes used in qualitative research, rendering other techniques like probability sampling as less useful.

2.3.1.3 Designing the Interview Guides

Semi-structured interview guides were developed for all interviews in order to provide sufficient flexibility at the same time as assuring that a certain set of areas was going to be treated.

First round interview guide

All the interviews performed along the first round made use of the same interview guide, consisting of a fixed set of topics, in order to keep consistency between the interviews (McQuarrie, 2006). Mainly open ended questions were used since they allow a dynamic interview and the follow-up of interesting topics as they surface (McQuarrie, 2006)[4].

[3] For the whole list of participants see Appendix G.

[4] For more details about the layout of the interview guide used during the first round of interviews, see Appendix H.

Second round interview guide

For the second round of interviews the questionnaires were tailored for each interview. Since the main focus of these interviews was to investigate the topics in detail, the interview guides were more exhaustive and contained more specific questions. The questions were still mainly open-ended for facilitating the in-depth exploration of each topic.

2.3.1.4 Conducting the Interviews

The first round of interviews was conducted from 10th to 23rd March, 2010, during which a total number of 10 interviews were performed. The second round of interviews was carried out between the 7th of April and the 4th of May, and covered in total 17 interviews. The following procedure was used throughout both the first and second round of interviews:

- The interviews were performed at one of the Alpha locations, mainly in the form of telephone meetings[5]; face-to-face meetings were held when possible.
- The interview guides were sent in advanced to all interviewees for allowing them to reflect on the questions before-hand.
- The time dedicated to each interview ranged from 60-120 min.
- Both members of the team used laptops for taking notes, which became the minutes from each interview. Some interviews were recorded on mobile phone and later being transcribed into minutes.

2.3.2 Secondary Data

Secondary data was collected for complementing the primary data collected during the first and second round of interviews. The intranet was the most frequently used resource, as it serves as a platform for accessing a large number of internal information sources, like contact information and data systems. The intranet was primarily used for accessing documentation on strategies and targets existing throughout the organisational hierarchy but also for gaining understanding of processes.

2.4 Data and Information Analysis

The methods used for processing the data and information obtained from both the primary and secondary sources of data are presented in this section.

2.4.1 KJ-method

The *KJ-method*, named after its creator Jiro Kawakita, is also referred to as "Affinity Diagram". It is used for organising and structuring large amounts of verbal data into categories and for describing their interrelationships (Bergman & Klefsjö, 2010).

The KJ-method was used for processing the data collected from the interviews and sorting them into categories, thus facilitating their later review and analysis.

[5] The most common set up of the interviews were telephone meetings due to the locations of the interviewees.

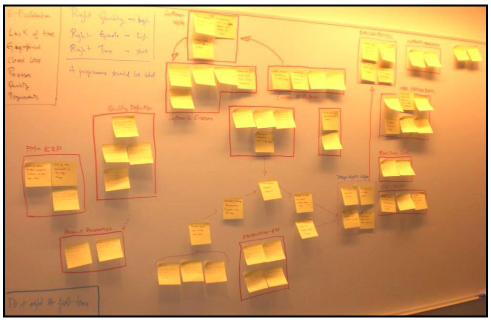

Figure 3: Result of one of the KJ method implementations along the Thesis.

2.4.2 Cause and Effect Diagram

The *cause and effect diagram*, also known as *Fishbone diagram* or *Ishakawa diagram*, is a tool used for organising causes and their possible effects in a logical and structured way. The diagram is often used during a brainstorming session for identifying possible underlying causes to an unwanted effect. (Keller, 2005)

The cause and effect diagram was used for organising the information derived from the KJ-method in order to identify possible problematic areas, their causes and how they affect each other. The method was also used for presenting solutions collected from the first and second round of interviews in a parallel structure.

2.4.3 DSM

The Design Structure Matrix (DSM) is a tool developed with the purpose of modelling and analysing complex systems (Institute of Product Development, TU Munich, 2009). The DSM can be used for representing a wide range of interfaces and their interdependencies, like interfaces between mechanical components or organisational departments. Moreover, DSMs can be implemented in order to represent either binary or numerical relations. Numerical DSMs are able to describe how strong each of these relations is, while binary DSMs are only able to describe the existence or non-existence of a relation (Institute of Product Development, TU Munich, 2009).

A main advantage of DSM lies in its ability to contain a large amount of information in a compact format. In addition, a number of algorithms can be applied for both analysis and optimisation purposes[6]. In this Thesis, numerical DSMs have specifically been implemented for modelling the communication and information channels between the selected departments[7].

According Wheelwright and Clark (1992) the pattern of communication, and the degree of cross-functional integration, are determined by four dimensions of communication: *Richness of media*, *Frequency*, *Direction* and *Timing* (see Figure 4). Further, they underline the importance of cross-functional integration in product development, especially in environments characterised by rapid changes in both market and technology.

According to Figure 4, the two extremes modes can be characterised. On one hand, sparse, low frequency, one-way and late communication corresponds to an *over-the-wall* approach, in which feedback is lacking. On the other extreme, the communication is rich, high frequent, two-way

[6] See Section 2.4.6 for further information about the implemented algorithm.

[7] The DSMs created in this Thesis are available in Appendix F.

and early performed, a mode which Wheelwright and Clark (1992) refer to as *integrated problem solving.* In it, upstream and downstream functions are closely linked in both time and space.

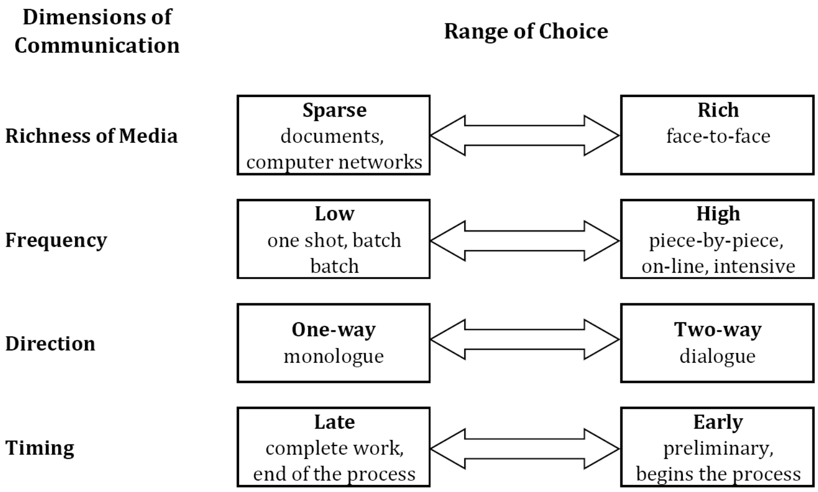

Figure 4: Dimensions of communication between upstream and downstream groups (Wheelwright & Clark, 1992).

In order to map the communication between MD and other departments, three out of these four dimensions were studied: *Richness of Media, Frequency* and *Direction*. During the first round of interviews, specific questions about the means (media richness), frequency and direction of the communication and information transmission were asked in order to model the three dimensions of communication.

With the data collected from the interviews, three DSM were created[8]:

- **Media Richness DSM:** describes the richness of the medium used for sharing information between departments. A three level grading was used for categorising the degree of richness: (1) document, (2) phone/mail and (3) meeting. A higher number is thus corresponding to a richer media type.
- **Frequency DSM:** the frequency of the communication is monitored: (1) when needed, (2) monthly or less and (3) weekly or more[9].
- **Role-Info DSM:** the actual content of the information transmissions is mapped to each department.

It is important to note that the richest media type was chosen in the case that a specific relation between two departments contained more than one type of media richness. This procedure was followed in order to reduce the complexity of the generated DSMs and to further simplify their analysis.

2.4.4 Business Process Modelling Notation

The Business Process Modelling Notation (BPMN) is a standard for modelling business processes. It was developed by the Business Process Management Initiative (BPMI) Working

[8] Section 2.6.4 discusses the effects of the chosen procedure on the later results.

[9] Because Media Richness and Frequency DSM are portraying the same communications, the same cells are filled in both matrices.

Group which released the BPMN 1.0 specification in April, 2004. The purpose of the BPMN is to provide a useful notation for analysts, technical developers, process users and process managers (Owen & Raj, 2003).

In this Thesis, the processes were modelled using the BPMN 2.0 notation due to its ability to describe both sequence and information flows. The standard also includes *pool* and *swim lane* notations, which allowed the mapping of the process functions to their respective responsible roles. The BPMN processes were drawn using Microsoft Word 2003, which placed restrictions on what symbols and notations that could be used. For an explanation of the notation used in this Thesis, see Appendix A.

2.4.5 Validation

Validation of data was carried out in cases of ambiguity, and when important details were missing in the interview minutes, in order to avoid misinterpretation of the data and for being able to draw correct conclusions. Five interviewees were contacted by e-mail with attached interview minutes and were asked to provide comments, to clarify possible ambiguities and to correct mistakes.

Four meetings of one hour each were held at Alpha, Lindholmen for validating the outcomes of the first round of interviews. All meetings were focused on the DSM matrices generated from the collected data. Since the available time and resources did not allow an extensive and thorough verification of all the collected data, and because of the MD scope of the Thesis, the MD-related data was prioritised. Thus, the validation meetings were delimited to only involve MD members; MD Engineers and a Line Manager were involved in these sessions.

Finally, an Operational Developer at the Project Office was contacted by e-mail for validating that the internal targets and strategies had been correctly understood.

2.4.6 DSM Clustering

Clustering is a technique used for dividing a data set into sub-sets. Clustering is used within many different fields, such as Data Mining and Pattern Recognition. The overall idea behind data clustering algorithms is to group similar data together, based on some kind of common feature. This common feature is often related to a defined distance measure between the data points (Russell & Norvig, 2003).

The interview outcomes resulted in a set of scattered DSMs which were not easily interpretable. Thus, an intermediate processing step was needed for facilitating their analysis. An algorithm developed by Thebeau (2001) specifically for clustering DSMs[10] was applied to both DSMs Strength and Frequency, in order to identify problematic areas, such as bottlenecks or lack of information sharing between departments. Figure 5 shows the process followed for clustering and analysing the DSMs.

[10] The algorithm developed by Thebeau (2001) was accessed through Instituite of Product Development, TU Munich (2009)

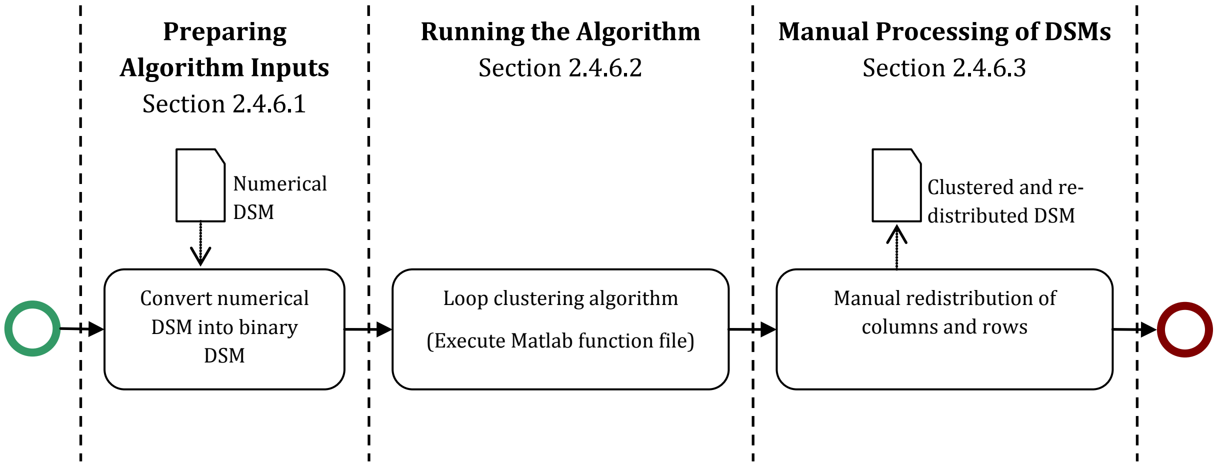

Figure 5: Process for clustering DSMs.

2.4.6.1 Preparing Algorithm Inputs

As stated in Section 2.4.3, numerical DSMs were implemented for modelling three communication degrees. Nevertheless, since the particular clustering algorithm was only able to cluster binary DSMs (Thebeau, 2001), it was necessary to modify the input data.

This was done by processing the Media Richness DSM through two separate DSMs. In the first, all (1), (2) and (3) were converted into (1), while in the second only the strongest relations were kept; all (1) and (2) became (0) and only (3) became (1).

As it has been said above, the original DSMs for both Media Richness and Frequency had the same cells filled. Thus, submit the Frequency matrix to the first procedure explained would have generated an identical matrix as Media Richness. This is the reason why only a third matrix was generated, converting just the high frequency relations; i.e. the (3) into (1) in the binary matrix.

2.4.6.2 Running the Algorithm

It is important to note that the clustering algorithm was used for facilitating the analysis of the DSM, meaning that the algorithm itself would not provide a "correct answer", in terms of an optimal number of clusters with the optimal sizes. In fact this problem of grouping a set of data points into K number of clusters constitutes what is known as a *NP-hard problem* (Mahajan, Nimbhorkar & Varadarajan, 2009). Since no algorithms are acknowledged to solve these problems efficiently, other approaches are used. One of these approaches is to use random algorithms, which is the case for the one implemented in this Thesis (Thebeau, 2001). This implies that the algorithm only guarantees a local optimum to be found, at the same time as this optimum may be different in different runs (Thebeau, 2001).

To deal with this fact a Matlab function file was developed, (see Appendix I), to allow multiple runs of the algorithm with tuned input parameters[11]. Indeed, Thebeau (2001) recommends the comparison of the outcomes of different implementations.

The Matlab function was executed according to the following procedure:

1. A DSM matrix was assigned as input to the clustering algorithm
2. The parameters *maximum_cluster_size* and *number_of_iterations* were specified

[11] The algorithm allowed the user to specify the maximum cluster size and the number of iterations.

3. The function file was executed
4. The output provided by the function was the clustered DSM matrix corresponding to the minimum cost[12] DSM generated over the complete set of iterations, defined by the *number_of_iterations* parameter.

The procedure above was repeated four times, in which the *maximum_cluster_size* parameter was changed to "14", "10", "7" and lastly "4" for each of the three input DSMs. Thus a total number of twelve clustered DSMs were produced.

2.4.6.3 Manual Processing of DSMs

The last step in analysing the DSMs was to examine the twelve clustered DSMs in order to identify similarities and differences amongst them. This procedure revealed that some matrices were essentially identical, with only a few switched rows and columns. Thus, through manual redistribution of some of the columns and rows, a total number of three unique clustered DSMs were produced. They are shown in Appendix F, numbered from M1 to M3.

In parallel, and based on the discussion in Section 2.4.3, it seemed relevant to investigate the combination of both the *Media Richness* and *Frequency* dimensions of the communication, which jointly give an indication of the intensity of the communication. For this purpose an **Intensity DSM** (M4 in Appendix F) was generated, multiplying the Media Richness and the Frequency DSMs and manually reordering its rows. A specific reordering of the Intensity DSM, according to the location of the departments gave place to the **Location DSM** (M5 in Appendix F).

2.5 Problem Solving

The combination of the *Problem Screening* and *Brainstorming/Synthesis* activities are in this Thesis conjointly referred to as Problem Solving (Figure 2). The screening phase was performed in order to extract the relevant findings for this Thesis from the complete set of collected data. Both DSM matrices and the cause and effect diagrams suffered a series of screening iterations in which the Theoretical Framework and the Problem Definition (Section 1.2) served as screening criteria.

The remaining problems were later on used as input to several brainstorming sessions (Keller, 2005) in which improvement concepts for each of the identified problem areas were generated. They are presented along Chapter 4. Of all these concepts, only one was further developed, reaching the status of improvement suggestion[13]. In order to improve and validate it, a number of meetings with both employees and external experts were held[14]. In addition, the authors attended to an introduction seminar to the new internal Trouble Report (TR) handling platform.

As can be seen in Figure 2, the definitions of the concepts of Premium and Quality were derived from the Theoretical framework (Chapter 3). It served as a parallel input to the brainstorming

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[12] *Cost* refers to how tight clusters the algorithm produces. A low cost corresponds to a DSM with clusters centered along the diagonal, while a high cost DSM corresponds to a scattered matrix.

[13] The improvement suggestion in issue, the LaPP process is presented in Section 4.5 and developed in Appendix B.

[14] These meetings are identified under the label *Idea generation* in the table shown in Appendix G.

session, in which they were combined in order to produce a suggestion of understanding of the concept of "Premium Quality" (Section 4.1.4).

2.6 Reflections

This section highlights some of the limitations of the methods presented in this chapter. Reflections are made in terms of both *inherent* limitations in the methods themselves and limitations imposed by the way they were *implemented*.

2.6.1 Qualitative approach

Since this Thesis deals with a qualitative approach, it is only possible to draw restricted conclusions. Qualitative research is carried out neither to obtain a measurement on how common an opinion is within a certain sample, nor to generalise these findings to a larger population. For achieving these purposes one need to rely on quantitative approaches. (McQuarrie,2006)

This implies that the results stated in this Thesis should be considered as indicators pointing at possible problematic issues and areas needed to be improved and thus cannot be taken for *truths*.

2.6.2 Interviews

As stated by Rugg (2006) "*interviewing is easy to do badly, and difficult to do well*", which implies that the interviewers must take care for not inflicting bias. Furthermore, the information obtained from an interview is limited, in the sense that it reflects a subjective notion from the interviewee. This emphasises the importance of the sampling procedure and how these results are used and interpreted.

Some limitations about the way the interviews were carried out are presented in the following list:

- Generally, the interviews were not recorded; instead notes were taken by the interviewers. Some information might have been lost due to this procedure.
- The most common set up of the interviews was the telephone meeting, due to the distance between interviewers and interviewees. The sound quality varied between interviews and in some cases it was difficult to completely understand what was said.
- After each interview, the minutes were clarified by writing out abbreviations and correcting sentence constructions, a procedure which often was very time-consuming.

2.6.3 Sampling

As previously stated in Section 2.3.1.2, the participants in the first round of interviews were selected in collaboration with the Alpha supervisors. It can be then argued that these interviewees were well known to the supervisors; hence they had a lot of interaction and communication with MD. However, this close contact raises the probability of most of them sharing a certain vision, thus inferring bias in the sample.

2.6.4 DSM

As it has been said in Section 2.4.3, a number of simplifications were made when converting the outcomes from the interviews into DSM matrices. One of them was to allow only one type of relation in each cell in the matrices for *Media Richness* and *Frequency*. This procedure implied a potential loss of relevant information, as well as overlooking potential problematic areas that became overstated.

Moreover, it can be questioned if investigating the timing of communication in relation to the development process –the fourth dimension highlighted by Wheelwright and Clark (1992)- would have provided more useful data, instead of investigating the frequency of communication between departments (see Section 2.4.3).

Further on, when analysing the DSMs, MD appeared to be more related to the rest in comparison to the other departments. This result can be viewed as an effect of sample bias, in terms of an MD overrepresentation within the interview sample and an over-dedication during the validation meetings.

2.6.5 Clustering

As described in Section 2.4.6, it was necessary to introduce further simplifications in order to be able to apply the clustering algorithm to the DSM matrices. These simplifications involved the procedure of translating the numerical DSMs into binary, thus degrading the resolution of the information contained in the original DSMs.

3 Theoretical Framework

The original interest of this Thesis revolves around the concepts of *Premium* (Section 3.1) and *Quality* (Section 3.2). They are the first to be introduced in this Theoretical Framework. Quality is a complex concept, which allows multiple definitions; nevertheless, the section about Quality is monopolised by Garvin's interpretation, which appeared to be the most relevant for this Thesis.

Section 3.3, Managing Quality, offers an overview of two different schools for handling quality in an organisational level, Total Quality Management and The Toyota Way. The inspection of these schools reveals that both converge in an ultimate goal, the Organisational Learning. Also related to quality, Section 3.4 presents Quality Function Deployment, a relevant tool for working with quality, which will be referred to later on.

For a full understanding of Organisational Learning, Section 3.5 introduces the term Knowledge, its types and the processes in which it is involved. Handling knowledge in the organisations requires a whole new discipline, the Knowledge Management. It is presented in Section 3.6, together with its processes that are related to this Thesis.

Eventually, Section 3.7 portrays the idea of Organisational Learning, its multiple interpretations and its relation with the PDSA cycle (Section 3.7.2). In parallel, Lean Product Development, introduced in Section 3.8, offers a set of interesting concepts for improving both the handling of knowledge and the quality performance.

Finally, Section 3.9 collects and relates the different exposed concepts, adding also the authors' personal contribution and interpretation to the created framework.

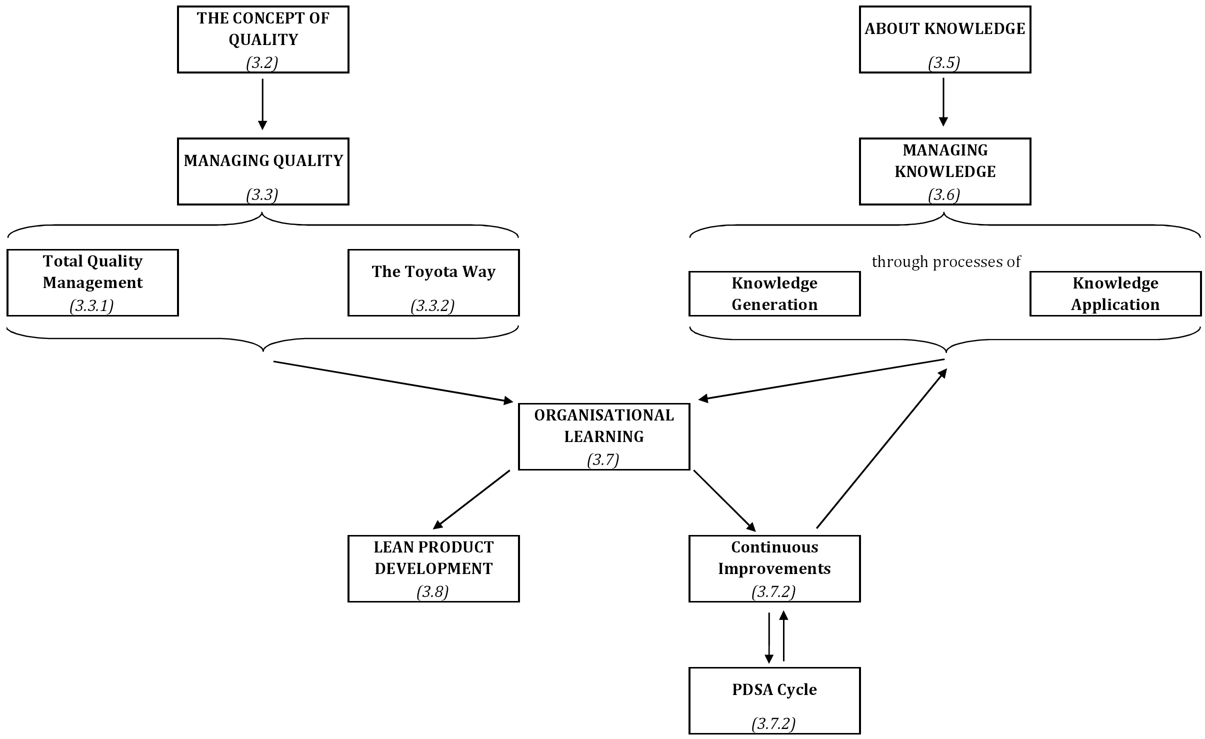

Figure 6: Reading guide of the Theoretical Framework chapter.

3.1 The Concept of Premium

The English word Premium appeared around the year 1600, as an adaptation of the Latin word *præmium*; in turn, it has two roots, "*præ-*" in the sense of "*before*", and "*–emere*", which means "*buy*" or "*take*" (Online Etymology Dictionary, 2010a).

Premium can be used either as noun or adjective. Its meaning as noun refers to a "*reward given for a specific act*" or a "*profit derived from booty*" (Online Etymology Dictionary, 2010a). Premium is currently used as a noun in contexts such as finances, marketing and insurances. In these fields, it refers to an additional item or an extra amount of money added to what was agreed (Random House, 2010).

However, it was not until 1928 when Premium was used as an adjective, for referring to the grade of a motor fuel (Online Etymology Dictionary, 2010a). Since then, Premium can be enclosed to a noun and provides sense of "*superior*" or "*exceptional quality or greater value than others of its kind*", equalling to "*higher price or cost*" (Random House, 2010).

3.2 The Concept of Quality

According to Bergman and Klefsjö (2010), the roman philosopher and politician Cicero (106-43 B.C.) was the first to use the term "*qualitas*", Latin root of the current word *quality*. "Qualitas" could be translated as "*of what sort*" (Online Etymology Dictionary, 2010b). This meaning can still be found in terms like *qualitative analysis*.

It was not until the 1930's when the term *quality* was discussed and applied in a product dimension (Bergman & Klefsjö, 2010). Since then, different authors have coined their own definitions for the concept. As they have focused on different areas, with weak connections between them, it is easy to experience a need for a global framework.

3.2.1 Five Approaches for Defining Quality

This disconnection between the alternative definitions is the reason which converted into relevant for this Thesis the work of David Garvin presented in this section, "*What does 'Product Quality' really mean?*" (Garvin, 1984). It provides a holistic framework for connecting the different, partial points of view. Garvin states that five different approaches are needed in order to get a complete picture of the concept of Quality:

- The Transcendent Approach defines quality as "*innate excellence*", something absolute that everyone would acknowledge. Only the exposition to objects with this ingredient could lead to the recognition and understanding of the concept.
- The Product-based Approach supports that quality is an "*inherent characteristic*" of an object. Any product can be analysed through a set of attributes, the eight dimensions of product quality shown in Section 3.2.2. The product-based quality is determined by the performance of the product in each of these aspects.
- The User-based Approach, in comparison with the previous approaches, holds that quality depends totally on the perspective of the user. A product with the combination of attributes which better meets the customer needs will be tagged with better quality.

- The Manufacturing-based Approach takes into account the process followed for realising the product. In the same direction, the better the product meets the requirements, the better the quality is, and fewer units will be scrapped.
- The Value-based Approach takes the cost and the price as starting points. From the user perspective, the performance must be achieved at an acceptable price; from the organisation perspective, the conformance should be reached under an acceptable cost.

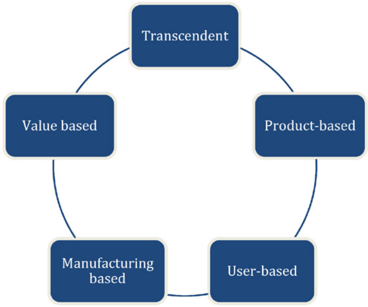

Figure 7: 5 approaches for defining Quality.

As it has been said above, different quality gurus have developed their own definitions of quality (Bergman & Klefsjö, 2010), which can be located in the framework drawn by Garvin. In 1951, Juran was referring to the user-based approach when defining quality as "*fitness for use*". Crosby and his "*conformance to requirements*" focused on the manufacturing-based approach in 1979, the same year when Taguchi and Wu supported a widened version of the value-based approach arguing that "*the lack of quality is the losses a product imparts to the society from the time the product is shipped*".

Garvin holds that it is essential for achieving high-quality products to consciously take care of all the different approaches, as each is useful to a certain part of the organisation. Indeed, the approaches should be earnestly shifted in each development stage.

3.2.2 Eight Dimensions of Product Quality

But Garvin (1984) did not stop here; in fact, he aimed to define the set of eight attributes, mentioned above, which form the basis for assessing the Product-based approach to Quality:

- The Performance is defined by the objective and measurable operational product characteristics which are of main importance for the user.
- The Features are those characteristics which are also objective and measurable, but that stand in a second degree of priority for the user.
- Reliability, which is based on objective measures of the probability of a product failure to occur within a given time; it gains relevancy when dealing with durable goods.
- Conformance takes both design and characteristics of the product and assesses them according to a certain standard.
- Durability refers to the "*amount of use one gets from a product before it breaks down and replacement is regarded as preferable to continued repair*". Both technical issues and the economic environment affect product results in terms of durability.
- The Serviceability refers to all the means used by the organisation for achieving a "*rapid repair and reduced downtime*", as well as their "*courtesy and competence*".

- The Aesthetics dimension refers to the appearance of the product in all the sensory aspects: look, taste, feel, smell and sound.
- The Perceived Quality plays a role when the customer must rely on indirect measures of the product, according to its brand or its advertisements.

3.3 Managing Quality

With the raise of the importance of the concept of Quality, several approaches to its management have been developed. In this section, Total Quality Management and The Toyota Way will be presented because of their relevance for later steps of the performed work. It will be shown how both share a close set of principles, which strive towards the Organisational Learning, one of the key issues of this Thesis.

3.3.1 Total Quality Management

The origins of Total Quality Management (TQM) come from "*Total Quality Control*", a book written in 1951 by Armand V. Feigenbaum (ASQ, 2010; Bergman & Klefsjö, 2010). Under different interpretations, it was rapidly adopted by the Japanese industry during the fifties (John Stark, 1998). During the early eighties, it was implemented by the US Navy (The Quality Portal, 2008), from where it became popular all around the western countries (John Stark, 1998). During.

TQM can be understood as "*a constant endeavour to fulfil, and preferably exceed, customer needs and expectations at the lowest cost*". Because of this wide perspective, other approaches like Six Sigma or Lean Production are methodologies or improvement programmes within the framework drawn by TQM. (Bergman & Klefsjö, 2010)

Despite the fact that different authors have their own definitions of TQM, they all base their perspective in a shared set of main principles, or *cornerstones* (Bergman & Klefsjö, 2010; Fisher 1995; Zu, Robbins & Fredendall, 2009):

- Focus on customers: carefully handle customer needs, expectations and service, as well as the assessment of their satisfaction. Promote the close contact with key customers.
- Base decisions on facts: make decisions upon the gathered, structured and analysed numerical and verbal data[15].
- Employee and supplier involvement: it can be achieved by continuous training, the delegation of responsibilities and the evaluation and reward of their quality contributions.
- Committed leadership: no quality improvements are possible without an involved leadership who participates and sponsors the quality improvement efforts.
- Focus on processes: the level of customer need satisfaction can be assessed using the data generated by the process; thus, the process itself can be improved.

[15] The Seven Improvement Tools and the Seven Management Tools, compiled in Bergman and Klefsjö (2010), may facilitate this process.

- Continuous improvements: the needs of the customer, the market and the competition are constantly changing; therefore, the duty is to continuously enhance the organisation's performance in terms of quality and cost.

3.3.2 The Toyota Way

For twenty years just after the Second World War, Toyota developed a business system alternative to mass production. Some American consultants inspected it during the late 1980s and labelled it as *lean production*, widely spread through the book first published in 1991, "*The machine that changed the world*" (Womack, Jones & Roos, 2007).

Later on, the concept became part of a more global term, *lean thinking*[16]. It is based on focusing on the customer, and it is the philosophy which has strongly facilitated Toyota's success as a car manufacturer. Because of its approach, lean thinking can support improvements in any area of an organisation (Womack & Jones, 2003).

During the early 1990s, a set of lean principles was detected in Toyota (Bergman & Klefsjö, 2010) which crystallised in "*The Toyota Way*", the book by Jeffrey Liker. Liker (2004) shows his picture of the management way of thinking of Toyota, including the Toyota Production System. Liker defines the Toyota Way as "*a system designed to provide the tools for people to continuously improve their work*". The Toyota Way, as TQM does as well, puts the Continuous Improvements as the mean to improve the quality in a sustainable way.

Among other paradigms and slogans, Liker (2004) structures his exposition around fourteen principles, organised in four different sections according to the pyramid defined by the 4 P – *Philosophy*, *Process*, *People and Partners* and *Problem solving* (see Figure 8). They all build on each other in order to reach the fourth and most important level, which involves the deployment of a learning organisation.

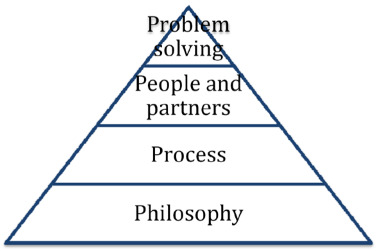

Figure 8: Toyota's pyramid of the 4 P´s proposed by Liker (2004).

- I - Philosophy: Make decisions based on long term philosophy, instead of on short term goals.
- II - Process: The right results will arise after working towards the right processes, based on continuous process flow, standardisation and rapidly addressing problems for getting quality right the first time.
- III – People and partners: Add value to the organisation with role-model leaders, developing people and teams, and challenging the suppliers to improve.

[16] Section 3.8 introduces the application of the lean thinking principles into product development.

- IV – Problem solving: Become a learning organisation by continuous improvements: solving root problems, reaching consensus when making decisions and relentless reflection.

For Liker (2004), problem solving is only dependent on the tool to an extent of twenty percent; the rest, eighty percent, depends on the people. Indeed, the people and the jobs depend on each other. A lean organisation requires extremely skilled and motivated people for performing the increasingly challenging jobs originated in a lean structure. And, at the same time, the only way to avoid the personnel to hold back knowledge and effort is to ask them to perform challenging tasks (Womack et al., 2007).

3.4 Quality Function Deployment

Quality function deployment (QFD) is a methodology developed by Shigeru Mizuno during the late 1960s (Bergman & Klefsjö, 2010) with the intent of achieving increased levels of quality, through systematically identifying critical customer needs and translating them into both product and process characteristics (Keller, 2005). QFD is currently implemented throughout a number of businesses and organisations (Bergman & Klefsjö, 2010).

Wheelwright and Clark (1992) state that QFD is aiming at answering three questions: "*What attributes are critical to our customer?*", "*What design parameters are important in driving these customer's attributes?*" and finally, "*What should the design parameter targets be for the new design?*" For successfully carrying out a QFD implementation, Bergman and Klefsjö (2010) point out four critical tasks which need to be performed:

- Identify customer needs and expectations through performing market research.
- Analyse products offered by the competition in order to estimate how well they fulfil the customer needs.
- Use the two previous steps for identifying critical factors which determine the success of the product on the market.
- Translate these critical factors into product and process characteristics.

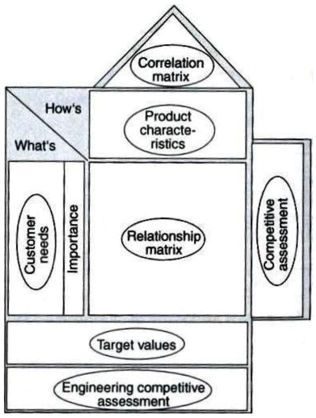

Figure 9: House of Quality (Bergman & Klefsjö, 2010).

The task of translating customer needs into product and process characteristics is facilitated by a modified matrix chart, known as *House of Quality* (HoQ) (see Figure 9). The HoQ is a planning tool specifically developed for assuring that the customer needs are fulfilled by one or more product characteristics[17] (Keller, 2005). The following lines describe the structure of the HoQ:

[17] "*Product characteristics*", "*design requirements*" and "*design parameters*" are used interchangeably by the different authors referenced in this section.

- On the left hand side, there is the list of *Customer needs*, the *What's*, thus constituting the rows of the chart. Each need is accompanied by an *Importance weight*[18] specifying its relative importance compared to the other customer needs.
- The middle field of the HoQ, called the *Relationship matrix,* is used for linking the customer needs to the *product characteristics*, the *How's*. In this way, a blank row in the relationship matrix reveals that the customer need in issue is not fulfilled by any of the product requirements. Correspondingly, a blank column shows that the product characteristic is not influencing any of the customer needs. The relationship matrix can further be provided with weights, indicating the strength of the relationship between the customer needs and product characteristics.
- Below the relationship matrix, the *Target values* of each of the product characteristics are specified.
- In the roof, the *Correlation Matrix* is used for describing the positive and negative interrelationships among the product characteristics, from a customer perspective. It can thus be used for analysing interrelationships, and making important design tradeoffs between product characteristics.
- Finally, in the right hand side, the *Competitor assessment* describes the competitor products ability of fulfilling each customer need. This field is useful in evaluating the company's own products in relation to the products offered by the competition, thus providing insights into where more development work is needed, as well as what product characteristics are providing possible market opportunities (Wheelwright & Clark, 1992).

3.4.1 The Four Stages

The QFD methodology does not only allow the translation of customer needs into *product characteristics*; instead, this can be seen as only the first step in a sequence of four stages. This sequence is described in Figure 10, which shows how the *Product Planning Matrix* is used in the first step, for translating customer needs into design requirements. The subsequent matrices are the *Part Deployment Matrix*, translating customer needs into part characteristics, the *Process Planning Matrix*, determining the process characteristics, and lastly the *Production Planning Matrix*, translating customer needs into specific production operations (Keller, 2005). Hence, QFD becomes a systematic methodology, assuring that customer needs are linked to each stage of the product development process (Bergman & Klefsjö, 2010).

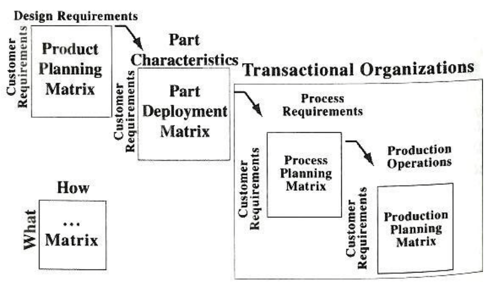

Figure 10: QFD stages with the associated matrices (Keller, 2005).

[18] Market research techniques such as Conjoint Analysis can be used in order to specify the relative importance of each customer need (Bergman & Klefsjö, 2010).

3.4.2 Opportunities and Challenges

Apart from providing a systematic and transparent way of translating customer needs into both process and product characteristics (Bergman & Klefsjö, 2010), QFD offers many other opportunities. According to both, Bergman and Klefsjö (2010) and Wheelwright and Clark (1992) QFD has been reported to offer a "*common language*", improving communication between design engineers and marketers, enhanced knowledge transfer and storage, and improved product designs.

However, Bergman and Klefsjö (2010) also point out the difficulties, encountered by Swedish companies when implementing QFD, in terms of lack of management support, resources and commitment within the project team. Further, an important aspect to consider is the number of requirements to handle. According to both Wheelwright and Clark (1992) and Bergman and Klefsjö (2010) the amount should be kept at a manageable level[19], focusing the attention to the most important customer needs.

In parallel, Wheelwright and Clark (1992) emphasise that when an organisation has learned how to carry out QFD, the formal aspect of generating the different HoQs becomes less important. Instead, the real benefits of QFD are gained through its ability to foster the discussion and analysis in each phase of the product development process.

3.5 About Knowledge

This section will give a brief background about the concept of knowledge, its types and the processes in which it is involved.

3.5.1 Knowledge in the Pyramid

Knowledge is neither data nor information, though it is related to both (Davenport & Prusak, 1998). A widely spread model for representing the relation between these items is the Knowledge Pyramid, shown in Figure 11. According to Qiu, Chui and Helander (2006), these three concepts are enough for portraying knowledge in product design, despite the fact that some authors add on the top terms like Wisdom[20] or Insight.

- Data is a set of discrete and objective facts about events. It contains no meaning, nor interpretation, judgement or indication about its relevance. (Davenport & Prusak, 1998)
- Information is data with added value (Davenport & Prusak, 1998), because it has been filtered, formatted and summarised (Qiu et al., 2006).
- Information becomes knowledge when it has been evaluated and organised, thus can be used for a specific purpose (Qiu et al., 2006).

While data is found in records or transactions, and information in messages, knowledge can be taken from "*knowners*" and routines in the organisation (Davenport & Prusak, 1998).

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[19] AT&T, a company with extensive experience in carrying out QFD, restricts the amount of requirements handled in the QFD process to around 25. (Bergman & Klefsjö, 2010)

[20] Wisdom is the evaluated understanding of the principles behind the knowledge (Gene Bellinger, 2004). This would allow using the right knowledge in the right way, and at the right time (We Know More, 2009).

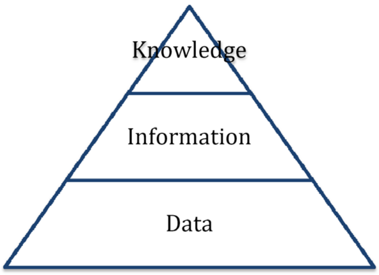

Figure 11: The Knowledge Pyramid.

3.5.2 Types of Knowledge

Two main types of knowledge are contrasted according to the literature:

- Explicit knowledge can be contained in documents, organised data, or computer programs (King, 2009). Because of this, this category includes knowledge about different issues (Smith, M, 2001; Garud, 1997). *Know-What* refers to what action has to be performed as a response to a certain stimulus (King, 2009); *Know-Why* covers the knowledge about principles and laws of nature (Qiu et al., 2006); and *Know-Who* deals with who knows something and who knows how to do it (Qiu et al., 2006). Grant (2008) summarises all these aspects with the label *Know-About*.
- Tacit knowledge; is defined by King (2009) in terms of knowing how to choose the correct response to a stimulus, while Qiu et al. (2006) add in it the skills and capability to perform this response; hence, is identified by E. Smith (2001) as *Know-How,* which involves skills that are expressed through their performance (Grant, 2008). Nonaka (1991) states that mental models and beliefs are also part of the Tacit Knowledge, apart from the Know-How. Tacit knowledge inhabits the minds of people and it can result difficult to articulate it (King, 2009). The concept of tacit knowledge is what is lying behind the statement "*We can know more than what we can tell*" (Nonaka, 1991), written by Michael Polanyi (1891-1976), one of the most important contributors to the philosophy of science along the 20th century (Smith, M, 2003).

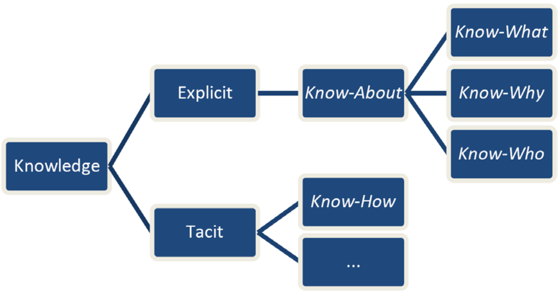

Figure 12: Hierarchic representation of the types of knowledge.

3.5.3 Four Modes of Knowledge Creation

Both explicit and tacit knowledge can be processed and transferred, generating knowledge of either its same kind or the other type. Nonaka (1991) describes these operations through the four modes of knowledge creation, shown in Figure 13.

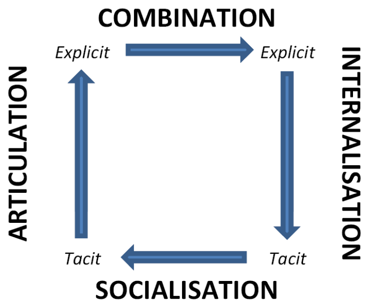

Figure 13: The four modes of knowledge creation described by Nonaka.

- Socialisation is found when tacit knowledge is directly shared with another individual. The transfer of master's skills to the apprentice is a clear example of this scenario. Nonetheless, the organisation cannot take an easy advantage of this knowledge since it is not converted into an explicit form.
- The Combination of information from different explicit knowledge pieces, like documents or meetings, allows the generation of a new chunk of explicit knowledge. This combination is in fact a synthesis, but it is not extending the available knowledge base.

According to Nonaka (1991), the two steps left are the critical ones in the knowledge creation process, since the individual in charge has to be actively involved in the task.

- Articulation can be found in the concept development phase when developing a product (Alfredson & Söderberg, 2009). It involves making tacit knowledge become explicit; in other words, taking something inexpressible and expressing it in some way. Nonaka (1991) defends the symbolism and figurative language as a good way for carrying out this process.
- Internalisation identifies the process in which the individual is expanding its own tacit knowledge using new explicit knowledge available.

3.6 Managing Knowledge

Knowledge management is the discipline that puts together all the processes and practices through which organisations take advantage of their knowledge for generating value (Grant, 2008). It is meant to manage both people and systems, and puts its accent on the contents, so that the relevant assets can be created, stored, disseminated and eventually applied (King, 2009).

The possibilities and procedures are different for managing both types of knowledge introduced above. On one hand, it is easy for the explicit knowledge to be transferred within the organisation, but also to leak to the competition. Because of this, the superiority of a leading organisation compared to the competition is not usually based on the amount of explicit knowledge in-house, unless it is protected by intellectual property rights or confidentiality. On the other hand, tacit knowledge is the key to the most relevant knowledge existing within the organisation, even though its management is much more challenging due to its nature. (Grant, 2008)

According to Grant (2008), the set of processes which belong to this discipline can be split into two main categories. The first category is aiming at the *Generation* –or *Exploration*- of knowledge, by creating or acquiring knowledge. Alternatively, Knowledge *Application* –or

Exploitation- gathers, amongst others, procedures much more interesting for this Thesis, shown below. The first two mainly deal with *Capturing* the knowledge gained during a project, while the two latter refer to how the knowledge is *Reused* later on:

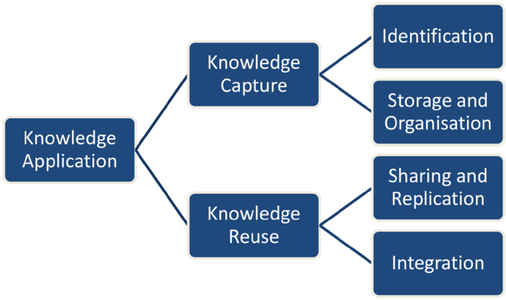

Figure 14: The most interesting knowledge processes described by Grant (2008).

- Identification focuses on recognising and documenting the knowledge generated in the organisation, so it can be stored and used subsequently.
- Databases are used for storing and organising information. The ease of access and communication of this information will facilitate the later transfer of knowledge.
- The knowledge can be shared and replicated in other parts or individuals of the organisation. Informal networks have recently won importance when sharing tacit knowledge
- The most of the organisational processes try so support an efficient and effective integration of knowledge from different sources for a successful good or service production.

3.6.1 Lessons Learned

Project-based organisations require good solutions for knowledge identification; otherwise, it is likely that the organisation will not take advantage of what is learned in the individual and independent projects. (Grant, 2008)

Lessons Learned are specifically one of these tools; at the end of the project, they collect the matters which can be relevant in the future. Alfredson and Söderberg (2009) identify different typologies and implementations of Lessons Learned. What they call *Post Control* is what is currently done in Alpha, as it strongly depends on the project manager and is oriented towards the reflection and the release of formal documents, instead of actual knowledge transfer.

3.6.2 Five Areas for a Closed Knowledge Loop

The implications to be considered when implementing a Lessons Learned platform were discussed in an interview with a Chalmers PhD candidate in the field of Knowledge-Based Engineering (Interviewee 8, 7th May 2010). According to him, in order to have good chances for succeeding with a closed knowledge loop in an organisation, four different areas have to be considered.

On one hand, a closed loop consists of two steps, the *capture* and the *reuse* of knowledge, described above. On the other hand, both steps require two ingredients: not only a good *technical solution* able to support the corresponding task, but also the *motivation* of the employees, supported by the organisational backup given in each step.

Indeed, a good technical solution –like a consistent database- will not by itself assure the start up and the running of the loop. Even though there is the risk of placing a large focus on the technology lying behind the process, the alignment of the organisational culture with the methodology to be followed, and motivation of the employees with long-term incentives are the key issues for achieving a successful closed knowledge loop. (Davenport & Prusak, 1998)

Grant (2008) highlights the importance of the credibility of the knowledge for its later reuse. In this direction, Alfredson and Söderberg (2009) underline the importance of the knowledge ownership; a knowledge owner would be responsible for keeping the knowledge up-to-date, and would appear as an easy-to-find expert in the subject. Thus, the knowledge ownership becomes the fifth area for the closed knowledge loop

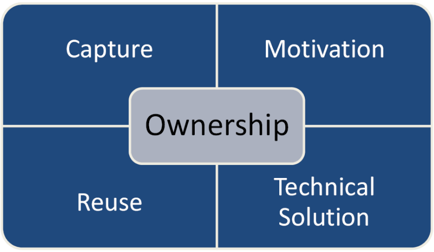

Figure 15: The combination of the capture, the reuse, the motivation and the technical solution draws the four required cells for a closed knowledge loop, supervised by the knowledge ownership.

3.7 Organisational Learning

Taking up again what was shown in Section 3.3 about managing quality, Organisational Learning is the main goal of both TQM and the Toyota Way. In parallel, King (2009) states that the point of Knowledge Management is to contribute to the achievement of Organisational Learning, since the latter seeks a sustainable use of the knowledge handled by the first. Summing up, Organisational Learning appears to be a key issue when dealing with knowledge, hence with quality.

3.7.1 Different Approaches to Organisational Learning

Several definitions and interpretations of the concept are shown along the Master's Thesis written by Alfredson and Söderberg (2009). Organisational learning aims at creating an environment for motivating people to detect errors and correct the corresponding root causes; this understanding of problems in a deeper level encourages a new way of thinking, based on continuous learning from the own mistakes, thus increasing the organisations capacity to create its future[21].

Nevertheless, development projects are not delivering organisational learning as an evident outcome; thus, learning from them is a big challenge for any organisation (Wheelwright & Clark, 1992). As a result, several authors have reflected about this scenario, and worked with new and suitable ways of thinking.

[21] This explanation is written by putting together the interpretations that Alfredson and Söderberg (2009) referenced to the definitions they collected from Magnusson (2008), Deming (1982), Argyris (1999) and Senge (1990).

In Section 3.3.2, the Toyota Way was highlighting the importance of reaching and solving the root causes, for instance by asking "*Why?*" five times (Womack et al., 2007). Wheelwright and Clark (1992) sustain that the quest for identifying the root causes leads to the understanding of the forces driving the development process, opening the possibility to change them.

Argyris and Schön (1974) come to the conclusion that the detection and correction of errors – which is their definition of learning- can be done in two different levels. The first level, or *Single-Loop*, tries to find an alternative way to reach the same purpose, without inspecting either altering the governing framework. The second level, or *Double-Loop*, goes one step further, since it also takes the "underlying norms, policies and objectives" into the critical judgement (Argyris & Schön, 1978). According to Agryris (1990), the rapidly changing contexts require this double-loop for making informed decisions[22]. (Smith, M, 2001a)

Peter Senge is one of the main responsible of the popularisation of the concept of the *Learning Organisation*. According to him, cause and effect are not always as close in terms of both time and scope as it is usually expected. This is the reason why the main building block for a Learning Organisation is to have *System Thinking*, referring to the prioritisation of a wide and global point of view (Smith, M, 2001b). Both the System Thinking and the Learning Organisation in itself are extremely important for handling the complex and continuously changing nature of the current business (Alfredson & Söderberg, 2009).

3.7.2 Continuous Improvements and the PDSA Cycle

In line with King (2009), organisational learning is achieved through "*continuous improvements*", referring to the identification and later institutionalisation of the improvements into the organisational processes. The inclusion of these processes into the organisational directives and their execution are meant to be much more relevant than the handled knowledge itself.

One of the most popular and extended improvement cycles is the PDSA cycle structured by Deming on the basis set by Shewhart. It offers a systematic way to analyse and solve problems, following four steps (Bergman & Klefsjö, 2010):

- Plan refers to identify an improvement opportunity, understand the environment of the problem and find an important cause.
- Do: carry out the agreed steps
- Study: evaluate the success of the implementation and keep the level if improved
- Act, in terms of decide about the focus of the next improvement cycle, whether to deal with the same or the next problem in the line.

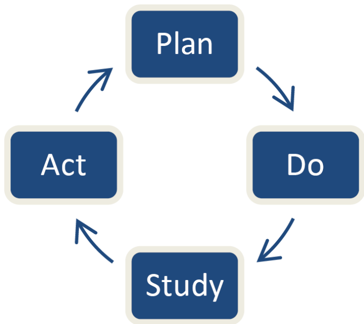

Figure 16: PDSA cycle suggested by Deming (Bergman & Klefsjö, 2010).

An interesting evolution of this learning cycle is the DMAIC, which is the framework used in Six Sigma projects. DMAIC stands for "*Define, Measure, Analyse, Improve and Control*" (Keller, 2005).

[22] This paragraph is an interpretation of the description by M. Smith (2001a), which references the sources quoted along the paragraph.

Six Sigma started at Motorola during the 1980s as a methodology for achieving strategic process improvement (Zu et al., 2009).

3.8 Lean Product Development

Whereas Section 3.3.2 presented the Toyota Way, which appears to be more of an organisational management guideline, the point of this section is to present the most relevant aspects[23] of implementing the principles of lean thinking into the product development processes, hence *Lean Product Development* (LPD) (Fouquet & Gremyr, 2008).

When switching from manufacturing into product development, a similar way of thinking can be applied –boost the value; eliminate waste-, even though a couple of changes must be clear. The first, that the resources in product development are human, instead of machines as in manufacturing (Oppenheim, 2004). The second is that the target is not to produce a product, but instead to develop, spread and reuse both information and knowledge (Alfredson & Söderberg, 2009).

3.8.1 Waste

Oppenheim (2004) believes that the product development process is still anchored in the craft way of working, and that is the reason for much of the waste that still exists in product development, such as lack of flow and pull, ad hoc planning and execution or large variability. However, Lean manufacturing succeeded in facing the waste from the manufacturing process; so should lean do with product development too.

Oppenheim (2004) refers to several authors for labelling three kinds of activities: *Value Adding* –to be kept-, *Non Value Adding* –to be removed- and *Required Non Value Adding* –required by contract or law-. According to different estimations, he states that the non value adding tasks monopolise a large part of the development times; thus, even though the value adding tasks have to be continuously improved, the largest benefits will be achieved by eliminating the two other types of activities, thus the waste they generate.

Seven sources of waste were labelled in-house Toyota after examining their manufacturing system; in addition, an eighth category has been agreed among the Lean experts (Locher, 2008). Locher (2008) suggested how these types of waste could be translated into product development process tasks. According to his research, the first four categories presented below are critical and ranked according to their presence in different types of organisations[24]:

- <u>Defects or Correction</u>: effort spent in fixing missing or wrongly processed information: design errors and the subsequent engineering change orders, the lack of information… This kind of waste can be reduced through continuously updating checklists and assuring their strict fulfilment.

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[23] These relevant aspects, *Waste*, *Standardisation* and *The Flow*, presented in the following sections, were selected according to their applicability in the Thesis work. Other interesting concepts, like the Value Stream, were discarded because of their complexity and the difficulties in accessing the required information for a proper usage later on.

[24] The last four are not sorted according to relevance.

- Non-value-added processing or Over-processing: when effort is spent in activities that are not needed by the customer; this is the case of administrative work, as re-entering data, or excessive paperwork. Re-design efforts –*re-inventing the wheel*- can be included here as well. This latter type can be caused by the ignorance about the existence, the bad accessibility or the lack of reliability of previous designs.
- Over-production or Over-engineering: to provide more information than what is needed, or too early. It also refers to the inclusion of features which are not seen as value. It can be caused by the lack of understanding of the customer needs.
- Waiting: in terms of time, waste can be defined as the difference between the lead time and the total process time; the most of this time is typically waiting –for resources, for approvals…-, thus impeding flow.
- Transportation: each movement of information, physical or electronic, is likely to decrease its quality.
- Excess Inventory: everything over the minimum needed for maintaining the information flow can be considered as excess: large design releases, long retention of documents…
- Excess Motion: travels, displacements to meetings…
- Underutilised People: skills of the staff members not fully used: not enough sharing of knowledge, people not involved in the process…

3.8.2 Standardisation

Any kind of improvements in the process cannot be performed until the process itself has been stabilised and offers predictability (Liker, 2004). Standardising the process, its tasks and the roles involved, is the foundation for achieving its desired stability and consistency (Mascitelli, 2007); hence, standardisation becomes the basis for the later continuous improvements (Liker, 2004).

For Liker (2004), when standardising the tasks of a process, it is critical to find a balance between the rigidity and freedom. The process must have some stiffness for becoming a guideline; but at the same time, a certain degree of freedom is needed for keeping innovation and creativity awake. At this point, what he called *Enabling Bureaucracy* gains in relevance. It refers to the combination of a highly standardised and bureaucratic technical structure combined with an enabling organisation when it comes to social relations and communication.

A standard process will not be used in the daily work unless it meets the users' requirements of simplicity and functionality, similar to the motivation and alignment to the organisational culture underlined in Section 3.6.2. The way to achieve this situation is by giving the process users the responsibility to, not only develop, but also to maintain and improve the standards continuously. (Liker, 2004)

In line with Locher (2008), the standardisation effort of many organisations is focused on the output from the stages instead of the work performed during the stage itself. From his point of view, this output-based standardisation cannot drive to sustainable results, since the truly effective standardisation requires a more thorough and work-based approach.

3.8.3 The Flow

Lean manufacturing aims at keeping the unit in process in a continuous flow, by the removal of waste and the alignment of value adding tasks (Liker, 2004). The same principle is translated into product development by switching the unit in process for the information about the product being developed.

The standardisation of the tasks, the coordination of their rhythms and the concurrent development made possible through the early involvement of the downstream actors contribute to the achievement of this flow, which will result in the enhancement of both productivity and quality (Liker, 2004).

Within a project, the flow is not always moving forward; instead, the loops and iterations are heading backwards. Locher (2008) distinguishes between *Bad iterations*, or mere reworks, and *Good iterations*, in which the organisation is gaining and learning something. Locher (2008) argues that the chances of a project to fall into a bad iteration are reduced when the knowledge reuse is increased. This interpretation motivates the idea that the flow should exist, not only within a project, but also towards the rest of the organisation, opening a new flow for feeding back the knowledge learned during the project.

3.9 In a Nutshell

- The use of the term Premium in a product perspective is currently used to specifically express the superiority of a product compared to the competitors.
- In contrast, Quality admits many more definitions. Garvin's interpretation offers a structure able to hold together different points of view about quality. Based on his article, the authors of the Thesis continued the work by suggesting the relation of Garvin's approaches with other interesting concepts, shown in Figure 17. It will be useful to consider the customer needs, the requirements and properties of the product as three columns.
    - The product-based quality can be considered as equivalent to the concept of *grade*, sometimes defined as "*fancifulness of the product*". It is considered to be determined by the demands of the requirements.
    - The manufacturing-based quality makes sense as the assessment of the product quality in front of the requirements that the internal customer had at the beginning of the development. In other words, the lighter the slope between the top of the requirements column and the top of the product properties column, the better the manufacturing based quality.
    - At the same time, the user-based quality can be understood as the evaluation of the product quality from the perspective held by the external customer and its needs, which were supposed to be satisfied by the product at issue. Using the same analogy as before, the lighter the slope between the top of the customer needs column and the top of the product properties column, the better the user based quality.
    - As the whole product development should be oriented in fulfilling these requirements and needs, both types of customers appear on top of the quality tree.

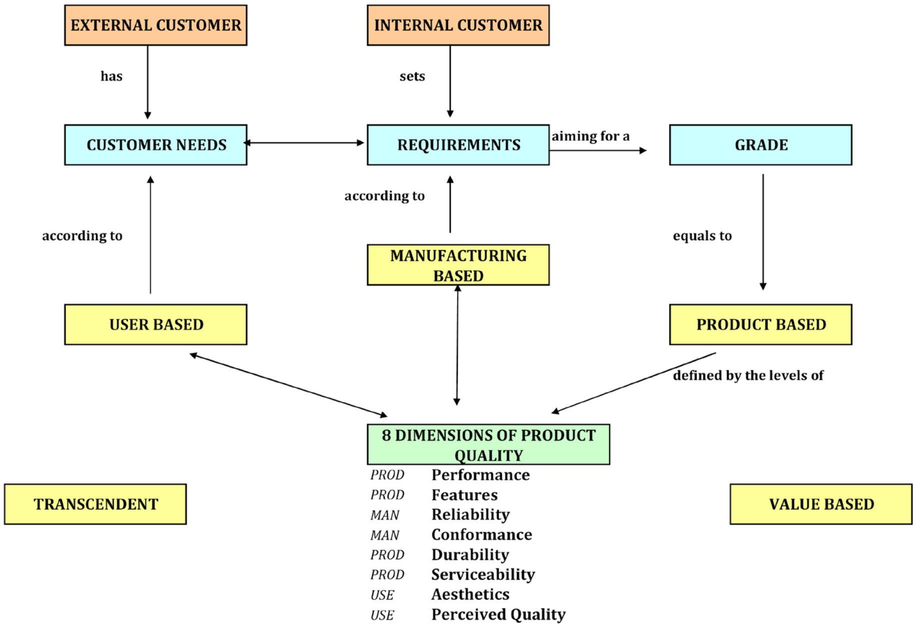

Figure 17: The Quality approaches and dimensions organised in a "tree" according to the interpretation of the authors.

- As Bergman and Klefsjö (2010) conclude, "*quality is more a relation between a product with its underlying organisation and the customer, than a pure product characteristic*".
- The inspection of relevant quality schools, such as TQM and the Toyota Way revealed that they both share quite many common cornerstones, converging in the organisational learning as one of their main purposes.

TOTAL QUALITY MANAGEMENT			***THE TOYOTA WAY***	
Bergman & Klefsjö (2010)	***Fisher (1995)***	***Zu et al. (2009)***		
Focus on customers	Customer service	Customer relationship	P1: Long term/customer	PHILOSOPHY
Base decisions on facts	Benchmarking	Quality information	P12: Go and see yourself	PROBLEM SOLVING
Focus on processes	Standards	Process management Product/Service design	S2: Right process, right results	PROCESS
Improve continuously	Innovative		S4: Organisational Learning	PROBLEM SOLVING
Let everybody be commited	Empowerment of people within the organisation	Workforce management Supplier relationship	P10: Develop the teams	PEOPLE AND PARTNERS
Committed leadership	Leadership	Top management support	P9: Grow leaders	PEOPLE AND PARTNERS

Figure 18: Comparison between the driving principles of Total Quality Management and the Toyota Way.

- The definitions given in the literature for the concepts of Knowledge Management, Organisational Learning and Continuous Improvements are blurry, and often almost contradictive, which means that the relations amongst them are extremely close. King (2009) defined Organisational Learning as the goal of Knowledge Management. In turn, and as it has been said above, the main purpose of Organisational Learning is the sustainable use of the available knowledge (King, 2009). Finally, from the perspective of Deming (1982)[25], the Organisational Learning should not be valued by the achieved goals; instead, its real purpose should be the achievement of Continuous Improvement processes themselves. That is why the authors perceive that all three, together with the PDSA cycle, can be drawn forming a closed cycle.

[25] Secondary reference from Alfredsson and Söderberg (2009).

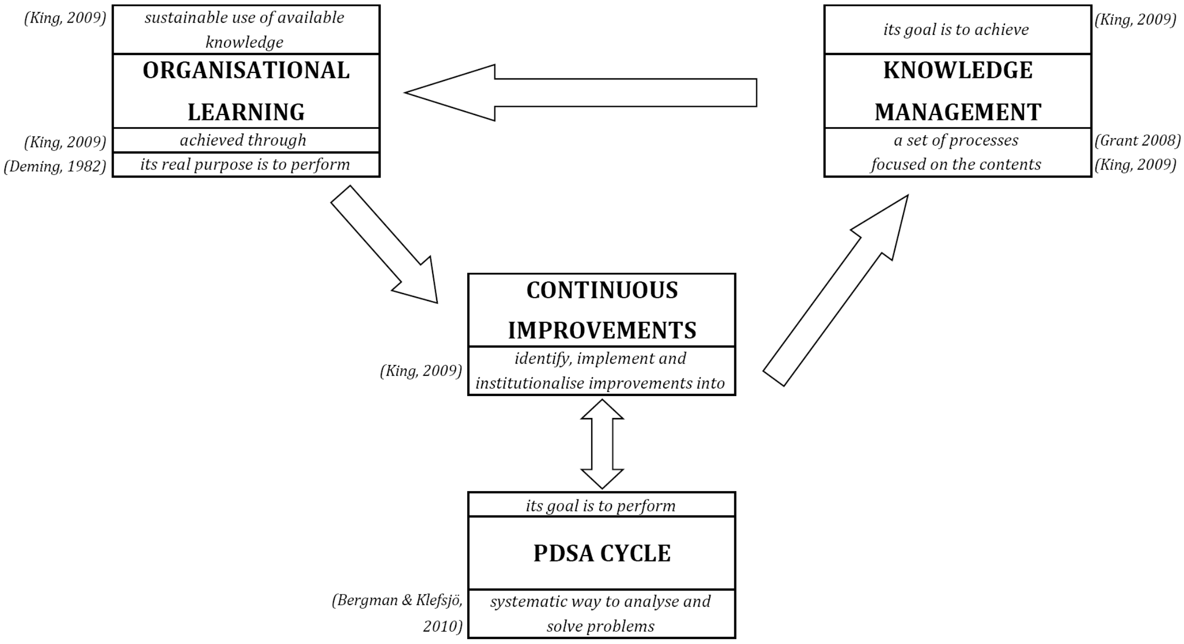

Figure 19: The definitions gathered in the literature for these four concepts relate them in a closed cycle.

4 Symptoms and Treatments

This Chapter, divided in three parts, offers a picture of the findings provided by the research and the subsequent analyses[26].

The first, Section 4.1, becomes a meeting point between the current state of Quality at Alpha and how the concept has been portrayed in the Theoretical Framework; the result allows drawing a definition of Premium Quality.

Section 4.2 presents structures used for collecting information from the manufacturing and the maintenance stages of the mechanical products. These structures become an example of what is lacking in the development process. At the same time, the information handled in these processes appears to be relevant in the new understanding of Quality proposed in the Premium Quality definition (Section 4.1.4).

The subsequent sections are organised according to the diagnosis performed from two of the quality perspectives: the external customer (user-based, Section 4.3) and the internal customer (manufacturing based, Section 4.4). Each of them is structured by presenting a set of *symptoms* which can be considered as critical for an increased quality performance at Alpha, including indications for *treatment*s to be deployed. Despite this division, the symptoms may become extremely interconnected. Out of all the improvement opportunities detected, only the LaPP process has reached a further developed state, thus deserves its own section, 4.5.

Finally, all the results are summarised in Section 4.6 as a bullet list of Recommendations for future activities to be carried on by MD.

4.1 About Premium Quality

A short description of how is Quality currently understood in Alpha gives some background to the definition of Premium Quality.

4.1.1 Understanding of Quality in-house Alpha

During the interviews, people from the different departments were asked about their own definition of quality. This uncovered that a number of different interpretations of quality exist throughout the contacted departments (Appendix D). Garvin's definition of quality, exposed in Section 3.2, becomes useful for integrating all these answers in a holistic framework.

Many departments showed their awareness of quality as the fulfilment of customer expectations, even though the opinions provided by the consulted customer appeared as not properly transmitted along the different departments. In parallel, certain departments expressed extremely constrained definitions of quality, only referring to their restricted areas of influence and concern.

[26] The different DSM matrices used, introduced in the Methodology Description section and numbered from M1 to M6 are available in Appendix F.

Only two of the consulted Alpha departments, Product Line Maintenance (PLM) and Integration and Verification (I&V), and one of the suppliers, offered a definition of Quality based on continuous improvement and the avoiding of repeated problems. This low awareness about learning as a cornerstone for Quality will be addressed again in Section 4.4.3.

4.1.2 Sharing Opinions about Quality

The dispersion in the definition of quality, presented in Section 4.1.1, is currently perceived as a problem, which can be summarised by what a system designer (Interviewee 26, 9th April, 2010) stated: *"Sometimes it is hard to get feedback if we have Quality or not, because Quality has a subjective definition"*.

This perception is also supported by a project leader within the Master and Quality (MQ) Department (Interviewee 33, 16th March 2010), who asked for more communication with MD in order to facilitate a common understanding of quality.

And this is the key. Garvin (1984) does not criticise the existence of different ways to understand quality, but states that "*reliance on a single definition of quality is a frequent source of problems*". According to this opinion, the different departments in an organisation, should defend and strive for fulfilling their perspective of quality. This implies that the approach to quality must be "*actively shifted*" along the different steps in the development process, as said in Section 3.2.1.

Nonetheless, these shifts in the interpretation of quality will not be possible if the different perspectives are not explained and understood. In other words, without awareness and respect from all the actors about all the possible interpretations, the efforts for improving the quality performance of the organisation may become slowed down. Garvin (1984) thus summarises that the organisation should cultivate the different views, as they all are important and necessary.

4.1.3 Premium Quality Parameters

Targets and strategies are used throughout Alpha as important means for working with both product and process quality. The performance towards these targets is monitored through the use of *Scorecards*. Within Operational Development (OD) (Interviewee 16, 12th April 2010), these Scorecards are seen as a Toyota-like tool; firstly, because they drive the continuous improvements efforts. Secondly, because they act as a visual communication tool, giving high visibility to the areas seen as important. Altogether, it is crucial that the information contained in the scorecards and target specifications is comprehensible and correct.

At the MD level, one of the targets is described in terms of "*Premium Product Quality parameters*". Nonetheless, the target does not reveal what these "*Premium Product Quality parameters*" are, how they are supposed to be interpreted or what implications they place on development projects and product characteristics.

Instead, the target specifies a set of clearly defined metrics, stating how they shall be measured, and what levels shall be reached for fulfilling the target. For mechanical products these metrics are based on measurements observed in one of the internal Alpha factories.

Although the target claims to measure "*Product Quality*", it can be argued that these metrics are in fact a measure of the process quality –i.e. manufacturing-based-, and only slightly approaching product-based quality in terms of *Conformance* to the manufacturing requirements (Section 3.2.2). The appropriateness of these measurements in this context can thus be questioned, a concern shared by an MD line manager (Interviewee 15th, 29th June 2010): *"I think we are not measuring product quality in the best way".*

4.1.4 A Definition for Premium Quality

The performed research has allowed the definition of Premium Quality in two different scopes.

4.1.4.1 In General Terms

Whereas Section 3.2 presented the concept of *Quality* through Garvin's five different approaches, Section 3.1 defined *Premium* as an adjective meaning "*exceptional quality or greater value than others of its kind*", which adds a relative comparison facing the competitors. Hence, the concept of *Premium Quality*, in general terms, can be understood as:

"*Be better than the competition in all the approaches and dimensions of Quality*"

Different interviewees released ideas and facts which can be understood contradictorily about the appropriateness of this definition for Alpha.

On one hand, from Product Management (PM) (Interviewee 2, 15th April 2010) there is a clear commitment in maintaining the technology leadership position that Alpha currently has in the market. In this direction, Alpha should definitely face the challenge of keep being better than the competition in all the fronts of quality.

On the other hand, it can be questioned whether reaching premium levels of quality is an appropriate goal for Alpha. According to a manager of OPM (Interviewee 1, 30th April 2010), the market has changed in the recent years. In his point of view, Alpha's customers are no longer asking for premium products; instead, they consider the products as commodities. A first consequence of this shift is that the brand is not taken into account when the customers choose their purchases. And the second, the customers will not buy something just because of its "*premium price quality*" –meaning higher quality, but also higher price-; instead, they will just look for the product that best suits their needs at an affordable price.

The representative of the contacted customer (Interviewee 40, 23rd April 2010) revealed the interest of his company in acquiring high-end equipment. However, this indication cannot be extrapolated to other competitors, and should be confirmed by more extensive market research.

4.1.4.2 For the Mechanical Design Department

Section 3.9 was useful for creating relations amongst the different approaches to quality, and understanding the quality as the *evenness* between the heights of the different quality columns. In parallel, and according to TQM (Section 3.3.1), the customer has to be always in focus, which converges with one of the current Alpha leitmotifs. Hence, the target for MD shall be to deliver products as close to the customer needs as possible. In fact, if the internal customer is also focused on the external customer when setting the requirements, it will be much easier for MD to contribute in the equilibrium between the different quality columns.

The reality is that MD is only supplying one part of the whole product; its function is limited to support and allow the device to perform its main function. Altogether, the customers do not have specific requirements about the product developed by MD; instead they are foremost interested in the main performance of the product.

"*The quality of the support systems is taken for granted*", said a manager of OPM (Interviewee 1, 30th April 2010). He also gave his opinion about the customers' point of view: "*They want to see the device only two times: when it is delivered, and when it is substituted*".

Hence, in his point of view, *reliability* is an important product dimension for quality. In line with this opinion, he (Interviewee 1, 30th April 2010) suggested indicators as the Return Rate, the faults found on field and the number of customer Trouble Reports (TR) as indicators of product quality.

Interestingly, from Integration and Verification (I&V) (Interviewee 42, 14th April 2010), Premium Quality was defined as "*the right quality at the right time*". Hence, the lead time, affected by the efficiency during development should also be taken into consideration. Yet another contribution was provided by a customer (Interviewee 40, 23rd April 2010): "*Quality is to fulfil the present and future needs*".

Altogether, Premium Quality can be defined in MD terms as:

"Efficient process and reliable product,
for fulfilling the present and future customer needs"

Thus, as a suggestion, the Premium Quality should be evaluated through indicators of project efficiency (knowledge reuse ratio, failures in the manufacturing plant), product reliability (return rate, customer trouble reports) and the fulfilment of customer needs (results of customer satisfaction surveys and forecasts).

4.2 Closed Loop Process Maps

The evaluation of these indicators, stated above, required the use of aftermarket data which was not used in the daily work of the quality drivers within MD. This is why it became relevant to investigate what information flows existed for feeding back this kind of information into MD.

The MD quality drivers had not a clear picture of how these processes and forums worked, in terms of what information they generated, who was the emitter and the recipient of this information and what feedback MD was getting. In fact, the available information about these processes was fragmentary and not easily relatable. Thus, a set of maps were specifically generated in order to increase the MD knowledge about these structures and awareness of what data could be used for assessing the quality performance of MD.

In parallel, the process maps should be seen as communication tools, which can be used both within MD as well as in the quality forums they portray. With these integrated representations of the processes available, it may become more likely the general discussion about the characteristics of the processes, their strengths and weaknesses.

Summing up, it is important to note that these maps were not used as a basis for latter analyses. The drawing of relevant conclusions about them would have required profound knowledge about how they worked, matter that was out of the scope of this Thesis.

The *Claims* and *Repair* processes are controlling the handling of faulty units. Depending on when a product fault is detected it enters in either the *Claims* or the *Repair* process.

In parallel, a set of quality forums exists throughout Alpha, with the purpose of working with product functionality and quality (Interviewees 11 & 20, 9th April 2010). They achieve this purpose through collecting statistics on manufacturing and aftermarket data, for identifying reoccurring problems found both at Alpha manufacturing sites and during service. When problems are detected, the corresponding forum has the mandate for initiating TR, Root Cause Analysis or DMAIC investigations securing systematic problem solving. (Interviewees 11 & 20, 9th April 2010)

4.3 External Customer Diagnosis

As presented in the Theoretical Framework, *Quality* is closely linked to the organisation and its customer. Starting from Garvin's attempt to define quality as a concept (Section 3.2), through its use as a philosophy in *The Toyota Way* (Section 3.3.2), to its management and implementation through *TQM* (Section 3.3.1) and *Lean product development* (Section 3.8), they all place the customer in focus.

This customer focus is articulated in TQM by its emphasis on understanding the customers and their needs, whereas the lean thinking connects this focus through the definition of waste (Section 3.8.1), thus providing strong reasons for an organisation to especially care of its customer interface. As seen in Section 3.9, User-based quality can be understood as the comparison between the customer needs and the extent to which these are fulfilled by both product and services.

This section presents, based on what the user perceives, three different focuses of problems which are currently challenging the user-based quality[27]: the dissatisfaction caused when the purchase delivered by Alpha does not match the expectations, the interaction between the product and its accessories and the product documentation[28].

4.3.1 Handling Customer Needs

Due to an improper handling of the customer needs, in terms of how they are collected, spread and understood, the customer needs are not always fulfilled which thus causes customer dissatisfactions.

According to the matrix M4[29], the communication between the Customer, the Marketing Department (MkD) and PM is both rich and highly frequent. However, from the customer's point of view (Interviewee 40, 23rd April 2010), the needs regarding the components developed by MD are not prioritised in the relation between both companies.

None of the four matrices (from M1 to M4) shows any direct interface between MD with neither MkD nor customers. This fact was verified by representatives from all, MD (Interviewees 3, 15 & 39, 17th May 2010), MkD (Interviewee 1, 30th April 2010) and a customer (Interviewee 40, 23rd April 2010).

Instead, the DSMs from M1 to M4 show that PM performs its role as link between the customer and the design process, connecting the top left cluster in M1 (Cs, MkD and PM) with System Design (SD) and MD. This is done through releasing a general requirement specification

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[27] The term *user* is used for an easier link to the Garvin definition, although it should be more properly called *external customer*.

[28] In this section, all the symptoms and all the treatments appear so related that all the improvement opportunities are presented together at the end of the section.

[29] All the DSM matrices, numbered from M1 to M6 can be found in Appendix F.

(Interviewee 2, 15th April 2010) ("*General Requirements*" in M6[30]), but also through participating in a meeting, Direct Input from Customer Meeting (DICM), in which direct input from the customers are discussed (Interviewees 10 & 39, 17th May 2010). Further on, these general requirements are used as input to the SD department, which decomposes them into a more detailed product requirement specification, later used within MD (Interviewee 26, 9th April 2010).

Thus, customer needs are in essence transmitted through a sequential information flow, starting at the customer, going through MkD, PM and SD to finally end up at the MD department in the form of a requirement specification. According to the definition of transportation waste (Section 3.8.1) every step in a sequential movement of information will, likely, decrease its quality, a phenomenon which today is perceived as being a fact by representatives of MkD and MD (Interviewee 13, 26th April 2010; Interviewee 18, 10th March 2010). From both sides, they perceive lack of traceability and visibility of how customer needs are translated into requirements, due to the number of filters between the customers and MD. The result is that the understanding that MD has about the original customer needs is less than optimal.

One of these filters is the SD department, a critical link between PM and MD. According to an MD object leader (Interviewee 18, 10th March 2010), SD is sometimes hindering an efficient transmission of customer needs into MD. At the same time, PM and SD members state that the communication between them is personal dependent. Even though this view is shared, they blame each other for this fact (Interviewee 2, 15th April 2010; Interviewee 26, 9th April 2010) thus reflecting a lack of standardisation (Section 3.8.2) of roles and responsibilities necessary for obtaining consistency in this matter.

Connecting again to the sequential flow of transmitting customer needs, there are a few important feedback flows going from MD to PM and SD. These are both the DICM meeting and the workshops between MD and PM for showing examples of concepts ("*Examples of concepts*" in M6). These two means aim at validating that designers' understanding of the requirements has been correct.

On one hand, MD designers (Interviewees 10 & 39, 17th May 2010) appreciate DICM, seeing them as well functioning. On the other hand, since the DICM is a recently added activity in the product development process, there is a risk they are not known by all MD object leaders and thus not always performed (Interviewee 15, 16th June 2010). Additionally there is a perception within MD that the project managers are neither committed to the common workshops, nor always interested in solving mechanical designers' doubts (Interviewee 3, 17th March 2010).

However, the distance between MD, MkD and customer does not only affect the transmittal of customer needs. According to an MD line manager (Interviewee 15, 29th June 2010) the products developed by Alpha are in some cases failing in fulfilling specific customer needs.

Concluding this exposition, the efficient transmittal of customer needs into MD appears challenged by the organisational distance to the Customers and MkD. The existences of intermediate filters, which add personal dependency to the transmission, generate certain types of waste as well as a not completely standardised procedure.

[30] All the DSM matrices, numbered from M1 to M6 can be found in Appendix F.

4.3.2 The Product and its Accessories

The distance between the customer and MD described in the previous Section is here further exemplified in terms of specific customer needs which are not yet fulfilled by Alpha's current products, thus affecting the user-based quality (Section 3.2.1). An important aspect here is that the customer may purchase only the MD product, or alternatively, purchase the MD product and a whole range of accessories offered by Alpha (Interviewee 15, 16th June 2010; Interviewee 40, 23rd April 2010). During one of the interviews, a customer (Interviewee 40, 23rd April 2010) reported a set of unfulfilled needs related to how the MD product interacts with its accessories and the environment.

Firstly, some MD products experience problems in certain environments. According to him, these issues have been communicated to Alpha for some time but no improvements have yet been offered by the Alpha portfolio (Interviewee 40, 23rd April 2010). Thus, the costumers are forced to invent their own solutions for minimising these undesired effects. These *defects*, and their *correction* through design rework, are one of the types of LPD waste presented in Section 3.8.1.

Secondly, the same customer (Interviewee 40, 23rd April 2010) underlined a current trend in the market, dealing with the replacement of obsolete MD products for more modern ones. According to him, there is no comprehensive documentation describing what necessary, supplementary changes need to be performed when switching the product (Interviewee 40, 23rd April 2010). This process, which should be as simple as possible, is instead slow and rambling, since the customers have to plan these arrangements by gathering the required information themselves. Again, this situation can be identified as a LPD waste in terms of *missing information* (Section 3.8.1).

The understanding of this situation was extended by a validation meeting with a MD line manager (Interviewee 15, 16th June 2010) which revealed the current low level of collaboration amongst MD and the department responsible for developing these accessories, i.e. the Accessories Department, which causes an unclear division of responsibilities between them. This situation reflects a lack of both system thinking (see Section 3.7.1) and standardisation (see Section 3.8.2), which is partly hindering the fulfilment of customer needs. The MD way of thinking seems indeed focused in making a good product, but misses the perspective of the product working as a whole, and how it interacts with its accessories.

4.3.3 The Product Documentation

From the MkD, there is a strong concern about the importance of the documentation as a contributor to the product quality: "*Quality is to have the correct product and the correct documents*". (Interviewee 13, 26th April 2010)

According to him (Interviewee 13, 26th April 2010), there is today an issue with Alpha's product information quality, referring to both, the electronic documentation offered to the customers, but also the physical documentation sent together with the delivered products which is often not optimal (M6[31]) (Interviewee 13, 26th April 2010).

As seen in M1 there is no direct communication between the technical departments and MkD. Instead, MkD relies on an internal database for obtaining detailed product information and

[31] All the DSM matrices, numbered from M1 to M6 can be found in Appendix F.

marketing material. Due to this lack of communication, the up-to-date state of this internal information source becomes critical.

However, none of these means are properly updated so far (Interviewee 13, 26th April 2010). This impression was also highlighted by a previous Master's Thesis developed at another MD development line.

This fact causes mismatches between what the customers order and what is delivered, due to the fact that product revision changes have not been updated in the database. According to an MD quality driver (Interviewee 27, 14th June 2010), a possible explanation to this fact is that the database is only updated when "major" product changes are made, in practice meaning once or twice a year. Thus, even though smaller changes are made in the product, they only become visible together with the major updates of the system. He also explained that MD is only involved in reviewing the information shown to the customers which is related to MD products; a TR is released for making changes to the information contained in the system.

4.3.4 Improvement Opportunities

From this Thesis point of view, solutions to these unsolved needs can be obtained through following closer the principles introduced in the Theoretical Framework; TQM (Section 3.3.1) and the Toyota Way (Section 3.3.2) highlight the focus on the customer, whereas Lean Product Development (Section 3.8) underlined the importance of the flow of information amongst the departments.

A low understanding of the customer needs generates certain problems and documentation issues, which themselves are causing customer dissatisfaction. The point here is to facilitate the understanding of the customer needs within the technical departments, and provide tools for a better collaboration amongst them. Both formal and informal means should be provided for a better performance in this process.

4.3.4.1 QFD

A formal tool for channelling this information is the *Quality Function Deployment* (QFD), a way of putting more effort on identifying and transmitting customer needs. As explained in Section 3.4, the methodology facilitates the systematic identification of customer demands on products, parts and processes.

QFD is also based on performing continuous competitor analysis. This aspect allows the identification of weaknesses existing within the own products, but more importantly to identify weaknesses of the products offered by the competition. The latter is thus highlighting possible market opportunities and therefore, seems relevant for Premium Quality (see Section 4.1.4).

Another advantage of QFD is that it provides a common language and framework which can be used by both engineers and marketers and thus help in overcoming inter-department barriers. QFD also promises a transparent way of translating customer needs into product requirements, at the same time as it can facilitate their understanding within MD. QFD, and in particular the "House of Quality", can also serve as a more general communication tool among the other participants involved in the decomposition of requirements, such as PM and SD.

The implementation of QFD as a formal tool would enhance the transmission of customer needs, thus reduce the possibility of still experiencing unfulfilled needs. However, as explained in Section 3.4.2, it requires both resources and commitment in order to be successfully deployed.

4.3.4.2 DICM

As explained in Section 4.3.1, the DICM meeting is a relatively new activity added in the MD development process. The DICM appears as a valuable feedback flow in order to assure a correct understanding of the customer needs among the designers. Thus a direct improvement activity is to increase the awareness of this meeting among the MD object leaders in order to assure its execution in all MD development projects.

4.3.4.3 Customer Information Revision

As it has been said above, not only the product but also the information is relevant when a good quality performance is pursued. The underlying causes driving to these information quality problems, both internally in Alpha, and externally to the customer have not been identified during this Thesis.

However, the findings do imply a need for an increased frequency of updates performed in the system and to assure that the reviews of the information contained in it are prioritised within MD in order to increase the level of user-based quality.

Finally, it is strongly recommended to Alpha, if these failures are confirmed by more thorough research, to analyse the knowledge management tools governing these tasks, for identifying the root-causes of why these databases are not kept with consistent and up-to-date information.

4.3.4.4 Informal Relations with MkD and Customers

Currently, the informal contacts amongst MkD and MD seem the most effective way of obtaining the needed information (Interviewee 13, 26th April 2010). Stronger relations between MkD and MD would be useful for improving both the understanding and transmission of needs and the quality of the product documentation, which would be formally handled by QFD and an improved version and management of the system used for showing product information to the customer.

In addition, both MD and the consulted customer requested increased formal and informal communication between them (Interviewee 15, 16th June 2010; Interviewee 40, 23rd April 2010), in order to avoid the steps explained in Section 4.3.1 and the upsets they cause.

4.3.4.5 Collaboration with the Accessories Department

A stronger collaboration between MD and the Accessories Department, together with a clarification of responsibilities, are key issues for enhancing the performance of the product and its accessories, and their user-based quality.

Even though customers might purchase products and accessories from different suppliers, adopting a *"integrated thinking",* through an increased collaboration between MD and the Accessories Department would still be preferable in order to take a step towards a system thinking.

MD should foster this interaction, and clarify the responsibilities for the documentation about the supplementary changes. The availability of this documentation would facilitate the customer's work when upgrading their products, thus increasing their perception of quality, as well as becoming a value adding service distinguishing Alpha from other suppliers.

MD, in cooperation with the Accessories Department, should also examine and understand the customer own-made solutions developed for overcoming the problems that the customers experience with the MD products. This kind of knowledge is extremely valuable for future development projects and services.

Summing up, the Alpha departments involved in developing and maintaining products and accessories should think about them as a complete system, collaborating for achieving better conjoint performance and offering supplementary services for reaching higher customer satisfaction, leading to increased levels of user-based quality.

4.4 Internal Customer Diagnosis

When dealing with Manufacturing-based quality, the product is compared to the requirements set by the internal customer. Thus, the question "*What does the internal customer see about the product?*" reveals the **long lead times** currently spend for the development projects and the **large amount of Product TRs**, which appear along the process as underlying concerns of the current development at Alpha. The following symptoms contribute, in different grades, to these concerns.

4.4.1 Design Changes with the Suppliers

A fluent relation with the suppliers appears in both approaches to quality management introduced above, as a cornerstone of TQM (Section 3.3.1) and also in the third P of the Toyota Way pyramid (Figure 8). An issue to take currently into account in Alpha is how the information about design changes is transferred to the suppliers, and how this process is handled.

Both suppliers (Interviewees 12, 17 & 23, 12th April 2010; Interviewee 43, 15th April 2010) asked for ways of working that allow quicker and easier adoption of the design changes. In fact, they both agreed that there are design changes occurring more and more often. This situation requires design iterations with the suppliers, skipping the "*right the first time*" way of thinking (Section 3.3.2), which causes the generation of larger numbers of product TRs and an extended lead time. To avoid this, a dynamic handling of the design changes is required, thus the following aspects take relevance.

According to a supplier (Interviewees 12, 17 & 23, 12th April 2010), certain templates and procedures for managing these changes do exist, but different stakeholders, within Alpha, in different locations use different criteria and processes. This fact can hinder the visibility of the changes in the PDM platform used by Alpha for transferring product information to the selected suppliers (Interviewee 39, 12th March 2010). This may be a reason for why the product updates do not seem to be always on time, leading to the manufacture of parts which are not according to the new releases, i.e. *defects*.

At the same time, the worksheets of the *Bill of Materials* (BoM) must be downloaded separately and manually, making it a time consuming task, which thus can be considered as *over-processing waste*, as it represents a non-value-adding processing of data. A second supplier (Interviewee 43, 15th April 2010) underlined the advantages of including MD contacts in the PDM platform, for an easier communication and problem solving.

4.4.1.1 Improvement Opportunities

The different departments and locations authorised to send design changes to the supplier shall agree upon a standardised way to emit them, as well as committing themselves in the usage of this standard. This would speed up the adoption of the changes, as well as reducing the defects. However, in an ideal state, there should be no design changes sent to the supplier.

MD shall push for revising and upgrading the rules and procedures of the current PDM platform, towards a better visibility of changes, traceability of files, the inclusion of technical contacts in the database and the development of a download function allowing the complete BoM to be retrieved at once, hence speeding up this process.

4.4.2 An Extensive Process

One of the I&V line managers (Interviewee 42, 14th April 2010) gave an explanation to the frequent design changes stated above: "*The design process is too extensive; in order to meet the deadlines, the personnel is forced to skip some steps*". According to him, these shortcuts in the process may cause quality issues later on.

Again, TQM and the Toyota Way express the importance of working towards the processes (Section 3.3). Furthermore, Alpha is continuously updating its development process, a complete and extensive guideline for product development projects; however, it has its drawbacks: "*It is quite good, but it is not easy to use: it can be hard to find the information in it*", expressed an MD designer (Interviewee 39, 12th March 2010).

"*It is so big that it might scare people to use it, especially newly employees*", said an MD object leader (Interviewee 18, 10th March 2010). At the same time this object leader (Interviewee 18, 10th March 2010) recognised the ease of suggesting changes in the process, although according to an I&V manager (Interviewee 42, 14th April 2010) "*it is not validated how people adopt the processes*".

The picture is then that development process used is a standardised, easily upgradeable but difficult-to-learn process (Interviewee 18, 10th March 2010), which people skips because the employees have developed some kind of know-how about using it. In other words, a tool for standardisation is used in a non-standard way.

4.4.2.1 Ways of Working Portrayed by the DSM

The amount of tasks described and assigned in the development process may be a reason for the long lead times. However, the analysis of the DSM matrices revealed ways of working, probably induced by the development process itself, which appear as interesting contributions to the long lead times.

The M3[32] matrix intends to map the departments which communicate more often, with a frequency under a week. It can be seen how its configuration adopts a clear shape of a *main stream* close to the diagonal along the matrix. The matrix in fact shows that the most of the departments only communicate frequently with one or two other areas. This is an indication that the development work is generally performed in a sequential way.

Matrices M1 and M4 points to the existence of a *big cluster* which, to a certain extent, seems to lead the development process because of two reasons. Firstly, the matrices show a strong interaction amongst the cluster members. Secondly, the inspection of the matrices points to the fact that they work as an important pole of the process, in terms of delivering and receiving information to and from the departments outside the cluster.

[32] All the DSM matrices, numbered from M1 to M6 can be found in Appendix F.

M4[33] defines a strong cluster amongst MD, Strategic Sourcing, Product Sourcing Management and the Suppliers. At the same time, M1 hints the close orbits of Production and Supplier Quality (SQ). It is interesting to see that neither the external customer (Customer), nor one of the internal customers (PM) is located within the core of this big cluster.

Finally, the intensity matrix M4 was reordered into M5, grouping together the departments which shared a common location. The point was to examine if the *geographical location* of the departments affected the communication between them, although no clear pattern or evident finding could be observed.

4.4.2.2 Improvement Opportunities

The process, its dimensions and how it is currently adopted seem to be problematic. In fact, Alpha has already started the development of a summarised version of its development process, a demand expressed from different points of view (Interviewee 18, 10th March 2010; Interviewee 42, 14th April 2010). Nonetheless, the old and complete version of the development process shall be kept as a backup reference, in case of need for guidance when facing bigger or unexpected problems.

This short version shall become the standardisation of the shortcuts that people is currently doing in the process, achieved through the articulation of the employees know-how about the use of the development process. MD shall take advantage of the knowledge extracted through the LaPP process, introduced in Section 4.5 for optimising this simplified version of the main design process.

This situation offers the opportunity of introducing more concurrent procedures into the process, which appear as needed after the inspection of the matrices. This improvement would have effect through a better transmission of the needs into the technical departments and the earlier involvement and collaboration of the design department with the downstream roles and departments.

In parallel, an improvement to perform within the framework of the internal customer diagnosis is the inclusion of the reduction of product TRs as target at the MD level. Including this in the MD Score Card would motivate the employees for participating in the LaPP process (Section 4.5).

4.4.3 Poor Knowledge Application

In the Theoretical Framework, the steps and the hints for knowledge application around projects were identified. In fact, the interviewees recurrently complained about the ways that knowledge is identified in the projects, how is it stored and the way it is reused later on (Section 3.6). The manufacturing-based quality is affected when the organisation fails in these aspects.

A Lessons Learned (LL) workshop (Section 3.6.1) is performed at the end of every Alpha project. Even so, they are not standardised: the way they are performed strongly depends on the object leader (Interviewee 18, 10th March 2010), and they mostly contain personal reflections (Interviewee 33, 16th March 2010). The generated presentation slides are stored in a database which is hardly accessed by anyone afterwards (Interviewee 39, 12th March 2010).

Something similar happens with the technical knowledge of the project. Despite that the LL sessions are supposed to collect technical issues, the general perception is that they fail in this

[33] All the DSM matrices, numbered from M1 to M6 can be found in Appendix F.

purpose. At the same time, all the CAD models are stored in a PDM system (Interviewee 18, 10th March 2010), although the existing search tool does not allow an easy reuse of these drawings (Interviewee 6, 8th April 2010).

With this weak structure for knowledge capture, it is not strange that the reuse of knowledge is failing as well. Indeed, in up to four different stages during the development, the process guidelines ask the object leader to check knowledge existing in-house, including previous LL workshops documentation (Interviewee 5, 28th April 2010).

Nonetheless, the difficult access to the information underlined before hinders this task, which depends on the object leader implication and his/her ability to navigate in extensive databases. Altogether, only the involvement of experienced people in new projects is currently promoting the knowledge reuse (Interviewee 33, 16th March 2010). The lack of a consistent closed knowledge loop, and the low organisational learning incurred, is emphasised by the fact, revealed in Section 4.1.1, that only two departments showed to be aware of learning as a relevant mean for achieving Quality (see Appendix D).

4.4.3.1 Need for a Pending Process

The structures responsible for channelling the knowledge extracted from the manufacturing and the maintenance projects, presented in Section 4.2, contribute by giving inputs into the *Continuous Improvement Council* (CIC), a newly created group which gathers information from different sources and centralises the quality findings within an MD scope in order to implement continuous improvements (Interviewee 16, 12th April 2010).

In the meanwhile between CIC meetings, the *CIC pre-screening* sessions follow-up and sort the issues to be discussed in the next CIC. The members and agendas for the pre-screening sessions are not fixed but change according to the findings to be discussed.

In contrast with the maintenance projects, MD has no similar structure. The design team meets periodically in the *Trouble Report* meetings, which highlight the most critical problems that have been found. However, the projects are not currently supposed to deliver knowledge into the organisation; hence, after the technical root-cause and the solution have been found, there are no mechanisms for taking the most out of these learning opportunities (Interviewee 27, 14th June 2010). The LaPP process suggestion described in Section 4.5 tries to help in the resolution of this issue.

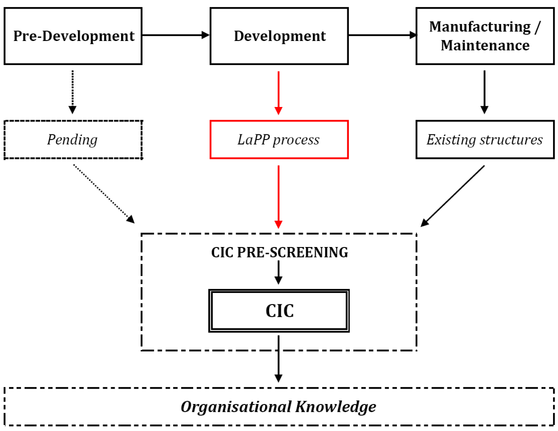

Figure 20: The existing structures channel the findings from manufacturing and maintenance. Neither pre-development nor development projects have an equivalent structure. LaPP is a suggestion for starting the development loop, whereas the pre-development loop is still pending.

4.4.3.2 Improvement Opportunities

The knowledge identifiable in a project can refer to both technical issues and soft/managerial aspects. The LaPP process, deployed in Section 4.5 intends to offer a standard way for identifying the relevant technical aspects of the project.

A still small group of employees is currently promoting an in-house developed method for conducting the LL workshops in a standardised way (Interviewee 5, 28th April 2010). MD shall consider the option of contacting these promoters for conducting from now on the LL workshops according this new standard, as a tool for handling the managerial lessons learned along the project[34].

4.4.4 Internal Production Requirements on the Design

The production equipment conditions certain aspects of the product. A good understanding of the internal production requirements on the product during development would allow a more production-oriented design, leading to a faster and more loop-free product development.

The relation between MD and Production can result in contradictory conclusions. According to the DSM matrices -M2[35] can serve as a good example- their relation appears to be excellent, due to both, the frequency of their communications and the usage of meetings and face-to-face encounters as their usual way of interacting as well.

Nevertheless, the collaboration is seen as too informal from an MD consultant's (Interviewee 6, 21st April 2010) point of view. In fact, informal contacts through some design for assembly workshops are conducted quite early in the project (Interviewee 30, 23rd March 2010).

In addition, on the other hand, the requirement specification has no room for collecting the requirements that Production has on the product. "*The needs of production are not documented. Instead, we need to talk to experienced colleagues or look at what has been done before for guessing ourselves*", says the consultant (Interviewee 6, 21st April 2010). The designers do not get the information about what production platform will be used until late in the design: "*It is hard to get thorough and documented opinions about the design on time*", states an MD line manager (Interviewee 15, 29th June 2010).

Finally, the existence of specific documentation focusing on design requirements has not been confirmed. The ability of skilled production engineers to adapt the production line to the product requirements hides even more the preferences of the assembly line (Interviewee 6, 21st April 2010).

4.4.4.1 Improvement Opportunities

A trend for improvement in the relation between MD and Production seems to go through complementing the current situation. Both sides are satisfied with the way they interact during manufacturing, supported by the exiting structures introduced in Section 4.2.

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[34] The improvement opportunities point towards a better identification of the knowledge coming out from projects. This might facilitate the later knowledge re-use, an aspect not directly addressed in this Thesis, thus appearing as a pending issue.

[35] All the DSM matrices, numbered from M1 to M6 can be found in Appendix F.

When it comes to the interaction during development, the standardisation of the formal relation appears as an area to improve. This could be tackled by the implementation of one of the steps of the QFD. Indeed, Keller (2005) describes the *Process and Production Planning Matrices*, which support a better management of the production requirements. They could possibly help in articulating the tacit knowledge held by the production engineers, in order to build a basis for avoiding re-works and over-processing in later developments, at the same time as addressing the current underutilisation of valuable resources, such as the production engineers (Section 3.8.1). The usage of a tool such as QFD would also allow the traceability of the requirements, simplifying the production transfers into new manufacturing sites.

Nevertheless, it is likely that Production Engineering people are not aware of the importance for MD to have all this documentation available. Thus, MD has a pending effort for convincing Production Engineering of, firstly, the need of formalised requirement documentation –for instance through QFD-; and in addition, the fast feedback and early involvement in development projects.

4.4.5 Recruiting and Selecting the Suppliers

Both TQM and the Toyota Way stress the importance for organisations to involve and improve their relationship with suppliers (Section 3.3). The sourcing departments in Alpha –*Strategic Sourcing* (SS) and *Product Sourcing Management* (PSM)- show a tight relationship, both between themselves and with the suppliers (M4[36]). Whereas SS deals more with the long term perspective of the relation (Interviewees 9 & 34, 15th March 2010), PSM continuously supports the projects through assuring that correct parts are purchased and delivered at the correct time (Interviewee 32, 18th March 2010).

Continuously, SS updates a list of recruited suppliers, which have passed certain criteria. These will participate later on in the process, driven by SS and PSM, for selecting the suppliers which will manufacture a certain component for Alpha during the next period, according to a combination of best performance and price (Interviewees 9 & 34, 15th March 2010).

The selection process starts by understanding the suppliers' ability of delivering the corresponding component in terms of amount, quality, time and cost (Interviewee 32, 18th March 2010).

The contacted people at SS assure that all suppliers who participate in the selection process are able to deliver the components with certain –and equivalent- level of product quality, as they have gone through the *recruitment* process (Interviewees 9 & 34, 15th March 2010). Nevertheless, MD has experienced that the level of the recruited suppliers is not always assured.

When talking about the supplier *selection*, and according to both MD and the SQ department (Interviewee 6, 8th April 2010; Interviewee 19, 11th March 2010), SS does not take the product-based quality into account. At the same time, the contacted people within SS agree that choosing the supplier is foremost based on a financial decision (Interviewees 9 & 34, 15th March 2010).

Interestingly enough, neither SS nor PSM have any opinion regarding product quality. Instead, SS defines quality as "*Right supplier at the right price*" (see Appendix D), thus reflecting a low concern regarding the concept of Product Quality.

[36] All the DSM matrices, numbered from M1 to M6 can be found in Appendix F.

The absence of shared understanding can thus be seen as problem rooted in a lack of communication between SS and MD, a fact confirmed by a product sourcing manager (Interviewee 32, 18th March 2010).

So, how is the involvement of MD in the supplier processes currently going? MD is involved in the preparation of the selection process, but MD collaboration is limited to appear as a contact resource for clarifying doubts about the request. Indeed, MD is not giving real input about important technical criteria for the selection.

An underlying problem is that employees at MD do not consider these supplier processes as scope of their project. The development process prescribes an early decision about the supplier strategy, but does not state how MD should be involved in these decisions. Maybe because of this, there has never been an organised way to defend MD opinions in front of SS. Instead, equivalent departments have been more determined, being proactive and developing a procedure for keeping SS and PSM aware of their needs and strongly defending their positions. (Interviewee 15, 29th June 2010).

Summing up, the DSMs reveal the existence of certain patterns of communication which, right now, their users do not take full advantage of: the knowledge and opinions of designers are not being enough utilised during the selection process.

4.4.5.1 Improvement Opportunities

The different views around the issue described in the previous section need to be understood and discussed among all the involved departments. On one hand, the financial and cost perspective represented by SS, on the other hand, the technical and product quality view of MD and SQ. As said in Section 4.1.2 about the Garvin's approach, all departments should defend their own vision of quality at the same time as being aware of all the others.

SS shall thus benefit from getting a deeper understanding of product quality, and especially what is needed from the suppliers in this aspect. Since SS claims to be "*total cost effective*" (Interviewees 9 & 34, 15th March 2010), the reduction of the CoPQ caused by good supplier selection will contribute in a better cost effectiveness in the longer perspective (Interviewee 37, 15th March 2010).

MD shall make an effort for increasing SS awareness. This could be achieved by presenting them the results of the direct impact (quality, cost, project lead time) of bad supplier selections on MD projects. The improved TR statistics tool, soon available, may result helpful (Interviewees 24 & 29, 10th June 2010). For going ahead in this aspect, it is required to have a fully operative list of categories for labelling the TRs in the MD scope. Although the work with this list has started, it is not completely developed yet.

In parallel, MD needs to become proactive in the supplier recruitment and selection decisions, increasing the Object Leaders awareness of the importance and the possibility of being involved in these decisions. The structure already developed at equivalent can be used as reference.

An example of this is that MD has recently started collecting technical criteria to ask for in the supplier recruitment (Interviewee 15, 29th June 2010). In this direction, one of the suppliers (Interviewee 43, 15th April 2010) expressed the convenience of sharing –if not the same, easily compatible- CAD software, in order to avoid slow and extensive file format conversions, which can be considered as *over-processing waste*, as it clearly represents non-value-adding processing of the data. This shall be a criterion to add in this MD list.

4.5 The LaPP process

Learning about Product and Process (LaPP)[37] is one of the improvement opportunities developed during this Thesis. It does not reach the level of implementation suggestion; hence there are still some issues to be solved, see Section 4.5.1, and contributions to be collected.

The whole LaPP process has been conceived for covering the blank existing in the knowledge application during design as described in Section 4.4.3, thus attempting to contribute in the continuous improvements of the development process. Its purpose is to structure the knowledge identification and the knowledge sharing and replication events into a standardised process. In the long term, it is intended to reduce the number of Product TR appearing during the development projects.

This will be achieved by two means. The first is channelling the technical solutions towards the responsible for their disclosure. The second is starting up process-oriented RCA, in order to find why the problem in issue eventually appeared and suggest ways to preventively avoid it in the future.

It has four main stages, in a PDSA-like process, and is driven by a quality champion, which takes the role of knowledge owner, an ingredient underlined in Section 3.6.2 as critical for a successful knowledge management. In order to gain credibility and back up, it is important that the process is aligned with the current quality structure. Under this intention, it has been planned extremely close to CIC pre-screening sessions and the CIC meeting described in Section 4.4.3.1.

As it was explained above, the projects generate a set of TR, highlighted by the TR meetings (Section 4.4.3.1). The innovation of LaPP comes as the most relevant TR from all the MD projects, which have reached a certain degree of criticality, are transferred to a list accessible to not only the object members, but also to designers from other projects and locations. This is done in order to get a wider perspective, approaching the system thinking introduced before.

Not all of these TR can be thoroughly analysed, thus some sort of screening task is needed. This screening would be developed in an interactive, forum-like application, taking advantage of the platforms already existing in the intranet. The intention is to allow people to rank the TR and discuss about their criticality and probability to appear again.

A set of selected people, driven by the quality champion, would perform the process-oriented RCA on the screened TRs, investigating the process and identifying why the problem appeared. The results are then presented to the LaPP activity, conducted as part of one of the CIC pre-screening meetings. In it, the quality champion would present the solutions for both, the technical aspects –found during the project- and the process approach –revealed through the RCA-.

The agreed results are then escalated into the CIC meeting which executes the upgrade of the organisational knowledge, through the modification of the process and the inclusion of the technical issues into the already existing *Technical Design Checklist* (TDCL).

[37] A complete description of the developed process is found in Appendix B.

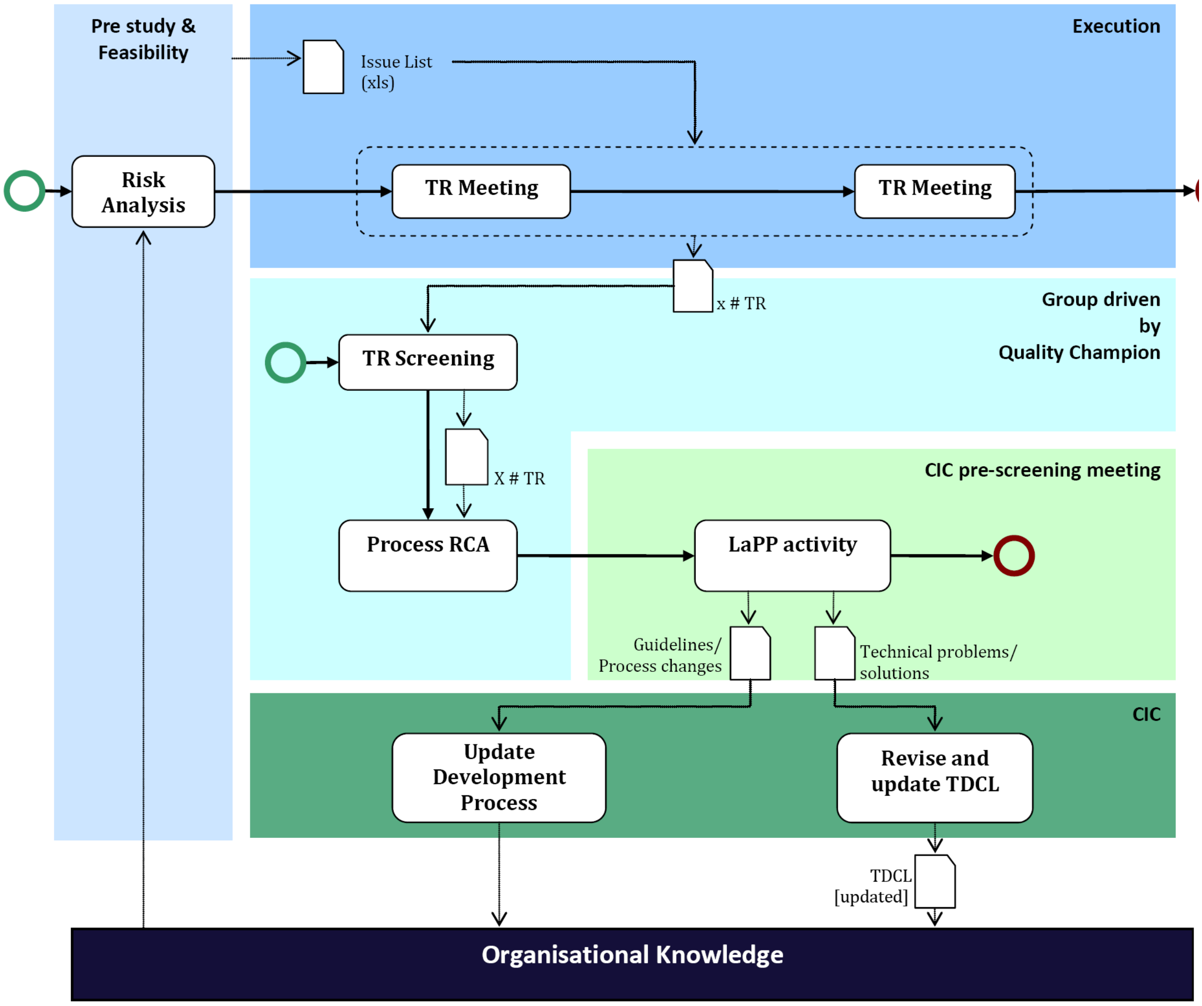

Figure 21: BPMN representation of the LaPP process.

4.5.1 Further development

A complete understanding and delimitation of the problem was achieved quite late in the Thesis work. Thus, the suggestion is not complete; neither has reached as much consensus as it was desired. Therefore, a set of pending issues are still to be solved.

- How many TR should be accepted out of each TR meeting?
- How should the TR be transferred into the open list?
- The usage of the intranet is not spread within MD; would people participate in a forum-like collaboration page?
- Is the process aligned enough with the normal working tasks of the designers?
- Will the Object Leaders be reluctant to show their problems to people from outside the project?
- What should be done with the TR that have already been analysed? Should they be kept or removed from the open list?

4.6 Recommendations

The following bullet list summarises the improvement opportunities relevant for MD. They are organised according to the 4 P pyramid presented in the Toyota Way section. The different philosophies suggested are easily separable into different areas, although these frontiers become blurrier when going up along the pyramid.

Philosophy

- Premium Quality: "*Efficient process and reliable product, for fulfilling the present and future customer needs*"
- Spread the Garvin tree of quality. Use it for a better understanding and awareness of Quality in the different departments.
- **User-based quality:**
    - Increase integrated thinking: product + accessories
    - Increase external customer focus
- **Manufacturing-based quality:**
    - Clarify traceability of targets between the different levels
    - Include Product Trouble Report reduction in the MD Score Card
- **Knowledge management:**
    - Prioritise learning and knowledge: projects should deliver knowledge

Process

- Reformulate MD Target in the Scorecard, including indicators about:
    - knowledge reuse ratio
    - return rate
    - customer trouble reports
    - results of costumer satisfaction surveys
- Use the data collected by the existing structures for evaluating the target fulfilment.
- Better Knowledge Identification through:
    - Strengthen internal use of the MD intranet site
    - Adopt the in-house developed standard for Lessons Learned workshops
    - Further develop and start up the LaPP
    - Release the categorisation for Trouble Reports belonging to Mechanical Design
    - Push for the release of Trouble Report statistics tool
- Revise methods of Knowledge Storage and Organisation:
    - Project Labelling
    - Part Labelling
    - Query tool
- Implement QFD for better transmission of customer needs and production requirements

People and Partners

- Increase awareness in MD about Supplier Decisions involvement with the results of the new Lessons Learned approach and LaPP
- Transmit MD opinions and needs about producibility revisions and production requirements to Product Engineering. Motivate them with Trouble Report statistics. Use QFD.
- Transmit MD opinions and needs about involvement in the Supplier Decisions to Strategic Sourcing. Motivate them with Trouble Report statistics and Cost of Poor Quality results.
- Strengthen relation with the Accessories Department:
    - Bring informal contacts
    - Assure release of documentation regarding supplementary changes

Problem solving

- Implement all the improvements that the deployment of these items will provide
- Continuously update this list

5 Conclusions

- The use of the concept of Premium Quality in a MD strategy was not properly and solidly stated. Indeed, the current way to monitor this concept was not based on comprehensive neither optimal indicators.
- Together with a definition for Premium Quality; "*Efficient process and reliable product, for fulfilling the present and future customer needs*", a set of alternative indicators supporting this definition have been suggested: knowledge reuse ratio, return rate, customer trouble reports and costumer satisfaction surveys.
- MD was not aware of the possibility of using certain information sources already existing within Alpha. The mapping of a set of processes and Quality forums provided in this Thesis is seen as a trigger for using these sources, and thus an opportunity for open the door to new ways of evaluating the quality targets.

- A big cluster of departments is leading the development process; neither the customers, nor the Product Management department are present in this cluster. The pattern of communications reveals an extremely sequential flow of the information. These two aspects can explain the current long lead times.
- Although one of the main Alpha's leitmotifs is to focus on the customer, there is in fact a quite big distance from MD to customers and Marketing Department. Indeed, MD does not properly perceive the external customer needs. As a consequence, MD's products are not focused enough in this user-based quality.
- Organisational learning is not prioritised in Alpha. The Lessons Learned sessions are currently driven in a way which hardly has identifiable advantages. Indeed, the available knowledge management tools for identification, storage and sharing of knowledge do not fulfil personnel needs and expectations. Because of this, product and project problems are repeated in consecutive projects.

- The recommendations offered in this Thesis suggest to MD a set of improvements in different levels of their ways of working. They contribute in the achievement of the quality definition that has been proposed and underline the importance of the continuous improvements as the only way to work with quality in a sustainable way.
- The treatment for several detected misunderstandings involves a mentality shift within MD, in terms of an internal clarification of what is desired (production requirements, involvement in supplier decisions) and a later discussion with the responsible roles.
- The LaPP process has received good critiques from different positions. Nonetheless, a number of issues, listed in the corresponding section, are pending to be solved for reaching a solid implementation suggestion.

6 Discussion

About the Thesis

- The scope of the Thesis was unclear and extremely wide in the beginning of the project. This fact subsequently caused a long and –maybe too- wide research. Huge amounts of data were generated, which incurred later processing tasks to become time and effort-consuming, a fact which came to be one of the biggest challenges for the authors.
- This wide research effort provoked two situations. The first was obtaining plenty of scattered, non-homogeneous information, hardly gatherable under coherent transversal axes. The second was the reduction of the time available for the development of improvement suggestions, which appeared as one of the most interesting points for the sponsors at the end of the period. As a consequence, the suggestions for improvements are not as deep and comprehensive as it was desired to deliver.
- Although they were not in the original scope of the Thesis, the developed work has generated several deliverables with big interest as communication tools, as the Closed Loop diagrams and the set of DSM matrices. According to the MD quality drivers, no one before had attempted to draw a comprehensive representation of the Closed Loop processes. Therefore, the authors expect that they become a useful tool in order to share visions, improve the corresponding processes and increase awareness about how they could be used for MD purposes.

About the Methodology

- DSM appeared to be an extremely powerful tool, but it required big and time-consuming efforts all along its usage. Firstly, its application involved extensive preparation and planning. Secondly, the manipulation of the matrices with the used tools was slow and delicate. And thirdly, the meetings for validating the matrices obtained from the research entailed certain difficulties, as non-used readers were not easily introduced into the method.
- In parallel, the suitability of the DSM for the final scope of the Thesis is debatable. Different aspects come together in this impression, as the qualitative research approach, the available resources, the low degree of validation of the matrices, and the major simplifications that data has suffered in order to be suitable for the later analysis.
- Some of the methods used or suggested (DSM, BPMN, QFD) appeared as an unknown techniques for the people in Alpha. They should be considered as tools for continuing the analysis and planning of organisational improvements

About Alpha

- This Thesis has provided the authors with the opportunity to meet and talk to people from many different Alpha departments, as well as digging into some of its processes and corporate strategies. All this reality has appeared extremely complex. A thorough research was required for understanding the relevant pieces of this large jigsaw. This task has resulted highly time and effort consuming, although the outcome has become satisfactory.

- Not many employees are familiarised with this complexity. Furthermore, neither the supervisors nor the most of the interviewees have given any specific guidelines about the way to investigate about the corporate strategy. It was not until very late in the research, and almost by chance, that it was found a clearer direction of what tracks and resources had to be followed for investigating its definitions and implications.
- Also in this same direction, it has been observed a lack of traceability of the targets and strategies along the different levels within the organisation. In fact, this circumstance was one of the root causes for the start of this Thesis.

About the Results

- The word Premium has connotations of expensive and exclusiveness. Because of this, the understanding of "better than the competition" may become hidden. This fact converts the usage of the word Premium as something discussable, since the main point of the suggested framework is the reliability of the product and the efficiency of the process, not necessarily a high price product.
- No abstract recommendations have been given, because of the interest of the sponsors in this Thesis to deliver something applicable in a short-term perspective. Thus, the recommendations are quite specific and close to the daily work. The employees have received them with interest, because they are related to issues they experience daily.
- It has been experienced how a combination of formal and informal communication becomes the most solid basis for an inter-departmental relation. It is not effective to have plenty of face-to-face communication if the agreements or discussed points are not documented and thus become traceable.
- The procedures and IT platforms are only a part of the solutions; the employees require motivation for the improvements to succeed. This is why it is important to be aligned with the organisation’s and employees’ ways of working when developing operational improvements.

About the authors

- This Thesis has provided the authors with some deeper knowledge about Lean Thinking, which has appeared as an extremely interesting philosophy. Because of this, the authors have also tried to *go lean* in certain steps and ways of working. This attempt to think in a different way has become positive, despite the insecurity involved in doing something new in a new way, together with certain disappointment for not being able to fulfil this attempt completely.
- Together with lean thinking, another lesson to extract of this Thesis deals with organisational learning and continuous improvements, key issues when building promising organisations. Together with the idea just stated above, the mistakes and the reworks can –and must- be considered as positive, as long as they provide learning to the individual, and this learning is later on spread to the people around.

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Appendix

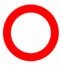
Appendix A	BPMN Notations
Appendix B	LaPP Implementation Suggestion
Appendix C	Garvin Quality Tree
Appendix D	Opinions about Quality in-house Alpha
Appendix E	DSM Reading Guide
Appendix F	DSM
Appendix G	Interviewees
Appendix H	Interview Guide
Appendix I	Matlab Code

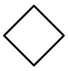
Appendix A BPMN Notations

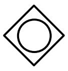
Graphical Elements

Flow Objects


Start event

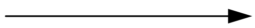

End event

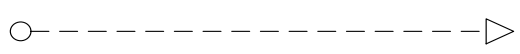

Gateway (XOR): Only one of several outputs is chosen


Gateway (inclusive or): One or many outputs are chosen


Activity

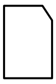
Connectors

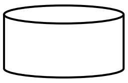

Sequence flow: Specify in what sequence the activities are executed


Message flow: Specifies messages between activities


Association: Associates artifacts with flow objects

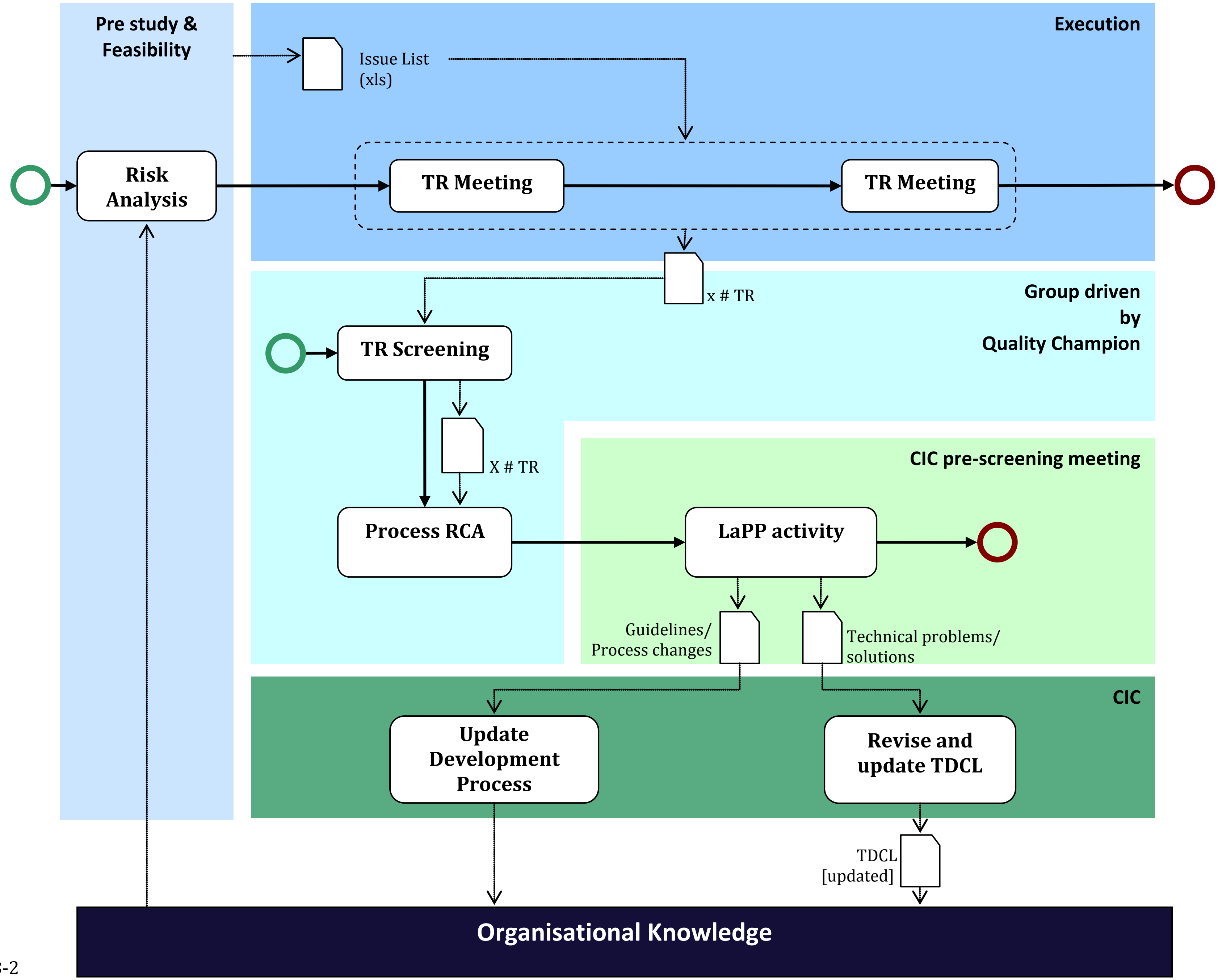
Artifacts


Data Object


Database/Data system

Appendix B LaPP Implementation Suggestion

- The following document contains a more detailed specification of the suggestion of implementation of the LaPP process.
- It consists of a process map according to the BPMN standard described in Section 2.4.4 and the Appendix A and the description of the different documents and meetings involved.


Pre study &
Feasibility
Execution
Issue List
(xls)
Risk
Analysis
TR Meeting
TR Meeting
x # TR
Group driven
by
Quality Champion
TR Screening
X # TR
CIC pre-screening meeting
Process RCA
LaPP activity
Guidelines/
Process changes
Technical problems/
solutions
CIC
Update
Development
Process
Revise and
update TDCL
TDCL
[updated]
Organisational Knowledge

Activities/Meetings

TR Screening

Participants (WHO):

- Quality Champion
- Object Members
- Other resources not affected by confidentiality restrictions

Screening Criteria (HOW):

- Criticality
- Time & cost effects
- Suggestions for root causes
- Re-occurrence of TR
- Re-usability of solution

Intranet Forum (HOW):

- x number of TRs (selected from the TR meetings) are uploaded to an intranet forum site where they are discussed and screened by the object members according the "Screening Criteria".

Incentives (WHY):

- The screening is performed continuously throughout the Execution phase
- Open TRs are included in the screening, thus designers responsible for each of the TRs will appreciate inputs from the discussion
- The Quality Champion assures that the screening results in a top list of TRs (X number of TRs), that they are investigated and that solutions and preventive actions are implemented.
- A better screening will result in a smoother TR meeting
- The process is validated through the, future, improved TR statistics tool.
- Increasing awareness of the importance of reducing the amount of TRs.
- Emphasis should be placed on the solutions and suggestions provided by the participants in the "TR Screening" activity.

Process RCA

Participants (WHO):

- Quality champion
- Employees normally involved in risk analysis
- The user that was/is assigned to the specific TR (if applicable)
- Other competences needed for investigating the TR

TR Meeting

Description:

- Critical TRs are discussed and followed up

LaPP activity

Learning about Product and Process

Participants (WHO):

- Operational Developers
- Robust Design Drivers
- Corresponding Quality Champion

WHEN:

- The LaPP activity is held as part of the CIC pre-screening meetings.

Description:

- The participants meet to agree upon the found Root Causes and the technical solutions to the TRs. The technical solutions and preventive actions are put into two documents:
    - *Technical problems/solutions*: serves as input to the "Revise and update TDCL" activity within the CIC meeting
    - *Guidelines/Process changes*: will be used in the "Update Development Process" activity within the CIC meeting.

Revise and update TDCL

Participants (WHO):

- Design owner
- Manager Project Office
- Manager System department
- Operational Development (meeting organiser)
- Robust Design drivers

Description:

- The TDCL is revised and updated according to the "Technical problems/solutions" document provide from the "LaPP activity".

Update Development Process

Participants (WHO):

- Design owner
- Manager Project Office
- Manager System department
- Operational Development (meeting organiser)
- Robust Design drivers

Description:

- Process changes according to the "Guidelines/Process changes" document provided from the "LaPP activity" are discussed, agreed upon and implemented through notifying the process owner.

Documents

Issue List (xls)

Output from:

- Pre study & Feasibility phase

Input to:

- TR Meetings

Description:

- List containing issues found in the object during the Feasibility and Pre study phase.

Guidelines/ Process changes

Output from:

- "LaPP activity"

Input to:

- Revise and update TDCL activity

Description:

- Document containing "hard knowledge" in the form of technical problems and solutions generated during "LaPP activity".

Guidelines/ Process changes

Output from:

- "LaPP activity"

Input to:

- "Update Development Process"

Description:

- Document describing changes in process(es), ways of working and design guidelines necessary for preventing TRs to re-occur.

TDCL

Output from:

- "Revise and update TDCL" activity

Input to:

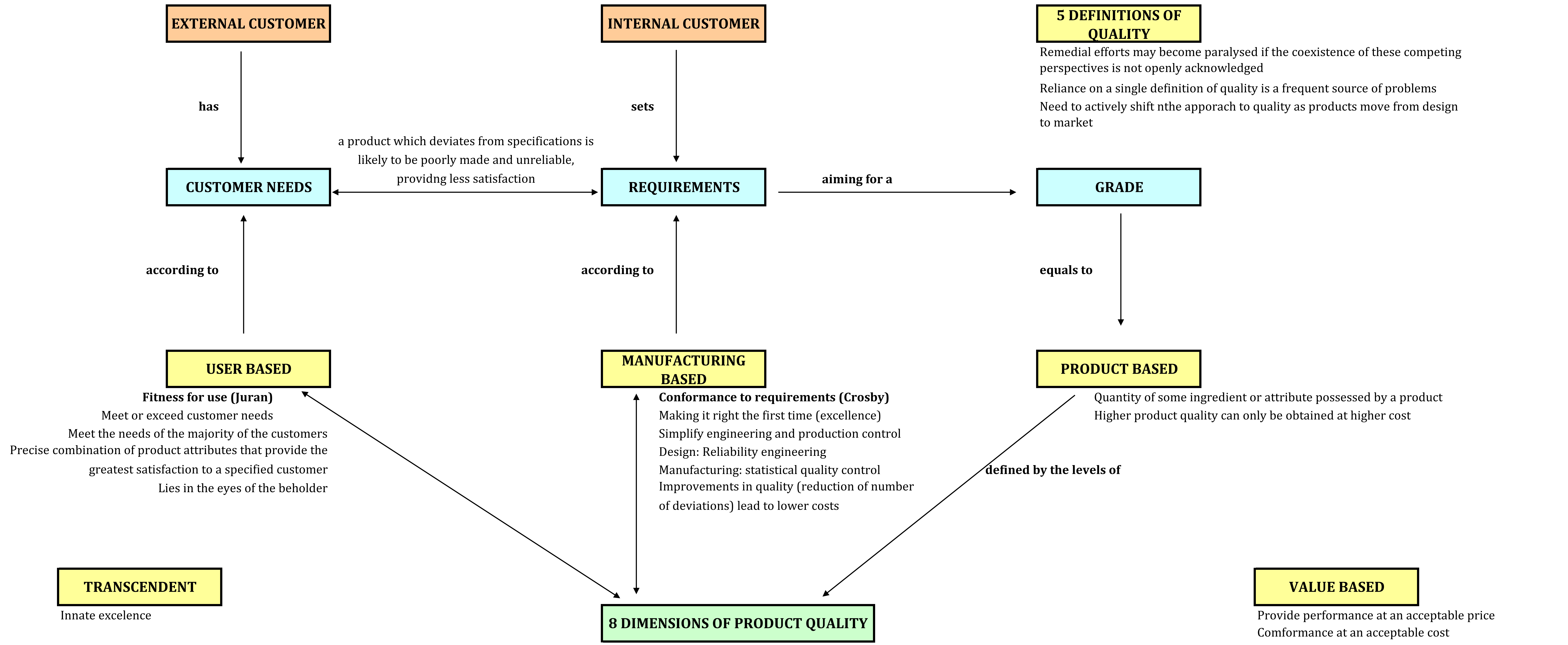
- To the Pre study & Feasibility phase. Also used during the "Risk Analysis" activity.

Description:

- Technical Design Checklist (TDCL). Document describing known design faults and corresponding solutions (design guidelines)

Appendix C Garvin Quality Tree

- The yellow boxes represent the five definitions of Quality suggested by Garvin.
- The eight dimensions of Product-based Quality are listed below the green box.
- In his theory, he indicates that each of the eight dimensions of quality is strongly related to at least one of the five definitions. These are indicated in the left of the dimensions
- The blue, the red boxes and the arrows are contribution of the author's of this Thesis



Together, they cover a broad range of concepts:
Several of the dimensions involve measurable product attributes; others reflect individual preferences
Some are objective and timeless, while others shift whith changing fashions
Some are inherent characteristcs of goods, while others are ascribed characteristics

PROD	**Performance**	primary operating characteristics of the product performance of a product would correspond to its objective characteristics; the relationship between performance and quality would reflect individual reactions
PROD	**Features**	secondary characteristics that suplement the product's basic functioning its translation into quality differences is also affected by individual preferences
MAN	**Reliability**	probability of product failing within a specified period of time
MAN	**Conformance**	degree to which a product's design and operating characteristics match prestablished standards
PROD	**Durability**	technically, amount of use one gets from a product before it breaks down and replacement is regarded as preferable to continued repair
PROD	**Serviceability**	speed, courtesy and competence of repair
USE	**Aesthetics**	how a product looks, feels, sounds, tastes or smells
USE	**Perceived Quality**	customer relies on indirect measures when comparing brands

Appendix D Opinions about Quality in-house Alpha

- The different opinions about Quality collected during the interviews are collected in the next two tables.
  - The first is exclusively dedicated to the Eight Dimensions of Product Quality.
  - The second gathers the opinions about the other Four Definitions of Quality.
- The yellow and green rows summarise what departments have expressed some opinion about each definition or dimension.
- The interviewees are referenced according to the numbered table in Appendix G.
- Some departments are grouped in the right hand side of the matrix. In these cases, it did not appear any of interpretations of Quality represented in the corresponding matrix.

	Interviewee	Cs	PM	MkD	SD	MD	MQ	S	PLM	I&V	SS	PSM	PE	SQ
PRODUCT BASED		X	X	X	X	X	X	X	X					
Performance			X						X					
Highest bitrates	1, 2		x						x					
Power efficient	1								x					
Features	2		x											
Weight, size	2		x											
Features		X	X	X					X					
Intuitively usable	2, 31, 40	x	x											
Not be injured nor hurt by the product	31		x											
Easy to install	1, 40	x							x					
You can handle it in one piece	1, 40	x							x					
Correct product and documents	13			x										
Very accessible	1								x					
Reliability			X		X	X			X					
Reliability	1, 2, 16		x			x			x					
Robustness	1, 2		x						x					
MTBF	2		x											
In Service Performance = 100%	26				x									
Dependability	2		x											
No fault found in any area	26				x									
Less degradation of quality than what the customer expects	6					x								
Stable	1								x					
Conformance									X					
According to conformance	1								x					
Durability		X	X					X	X					
Durability	2		x											
Technical life time	2		x											
Satisfactory product	43							x						
Operate without problems	40	x												
The system survives as far as possible, even with errors	7								x					
Fail to safe	7								x					
Serviceability			X			X	X	X	X					
Satisfactory service	43							x						
We have to deal ok with the problems	16					x								
Correct delivery	2		x											
Quick response to failures	33						x							
Easy and fast to repair	1								x					
Not require urgent actions	7								x					
Planned and regular maintenance	7								x					
Easy repairs without interrupting traffic	7								x					
Correct fault pinpointing: one error, one alarm, and the correct alarm	7								x					
Aesthetics		X	X			X			X					
Look and feel	16, 31		x			x								
Solid impression in the field	40	x												
Appearance of new, even after repair	7								x					
Appearance for convincing the buyers, the people who have the money in the fair	18					x								
Perceived Quality														

	Interviewee	Cs	PM	SS	PSM	SD	MD	PE	MQ	S	PLM	I&V	MkD	P	SQ
TRANSCENDENT							X	X							
Aim for perfection	*30*							x							
Things that give the perception of Quality	*6*						x								
Extras (tricky to find) out of the requirements	*6*						x								
Feeling and impression	*6*						x								
USER BASED		X	X			X	X	X	X	X	X				
Fulfils customer expectations, and more if possible	*4, 30*							x	x						
Fulfil customer expectations	*2, 15*		x				x								
Fulfil customer needs	*2, 43*		x							x					
Assure customer satisfaction	*26, 43*					x				x					
Fulfil customer requirements	*2*		x												
Fulfil present and future needs	*40*	x													
Judged only by the product, no brand	*1*										x				
It is taken for granted that enclosure has quality	*1*										x				
MANUFACTURING BASED			X	X	X		X	X	X	X		X			
It works	*30, 33, 39*						x	x	x						
Fulfils requirements	*39, 42*						x					x			
Fulfils designer specifications	*32*				x										
How many requirements are fulfilled	*2*		x												
Degree of fulfilment of the requirements	*2*		x												
All parts fit together	*4*								x						
Easy to produce and assemble	*3*						x								
Efficiency and capability of the process	*43*									x					
Correct Time to market	*2*		x												
Delivered at the right time	*2, 3, 30, 42*		x				x	x				x			
Do the right things	*3, 30*						x	x							
Check input and output	*30*							x							
Right supplier, right price	*9, 34*			x											
Continuous improvement	*42, 43*									x		x			
Not repeat problems	*1*										x				
VALUE BASED			X				X				X				
Delivered at the right volume	*2*		x												
It has the right price	*3*						x								
Customers will not pay for something they do not want	*16*						x								
No overperform: know the limit and reach it	*18*						x								
What creates value for the customer	*1*										x				
Less redundancies, and make the main system to work	*1*										x				
High ratio MTBF/price	*7*										x				

Appendix E DSM Reading Guide

There is no standard way for how feed forward and feedback flows should be described in a DSM; different approaches are used depending on who is implementing the specific DSM. The figure below provides an example on how the Media Richness DSM was implemented in this Thesis. However this example can also be viewed as a general description for how to interpret the other types of DSMs used throughout this report.

		Department A	Department B	Department C
		Provides output to		
Department A	Gets input from			3
Department B				1
Department C			1	

3	meeting
2	phone/mail
1	document

Some important characteristics can be seen in the figure above.

- First, reading across the last row, corresponding to *Department C,* shows that this department gets input from *Department B* in the form of a document, denoted by a “1”.
- Secondly reading across the middle row shows that *Department C* provides output to *Department B*, thus this is how both feed forward and feedback loops can be described using DSMs.
- Lastly, studying the first row in, it is seen that *Department A* and *C* are involved in a meeting, denoted by a “3”.
- Finally, since a meeting by definition involves both direct feed forward and feedback flows the “3” is only put in the upper diagonal of the DSM.

Appendix F DSM

- Page F-2 contains the Media Richness and Frequency DSM originated from the interviews, and their subsequent validation
- Pages F-3 and F-4 contain the matrices resulted from the clustering process, matrices:
  - M1 – Media Richness_1
  - M2 – Media Richness_2
  - M3 – Media Richness_3.
- Page F-5 shows matrices originated by post-processing of the original matrices not related to the clustering:
  - M4 – Intensity
  - M5 – Location matrices
- Page F-6 presents the matrix which relates the departments with information:
  - M6 – Role – information

Original Matrix for Media Richness

		Cs	PM	MkD	SS	PSM	SD	MD	P	PE	MQ	SQ	S	PLM	IV
THE INPUT THEY USE COMES FROM		THE OUTPUT THEY GENERATE IS SENT TO													
Customers	Cs		3	3											
Product Management	PM			3			3	3	3			x			
Marketing Department	MkD														
Strategic Sourcing	SS					3		3			3		3		
Product Sourcing Management	PSM							3	1			3	3		
System Designers	SD							3							3
Mechanical Design	MD								3	3	3	1	3	3	3
Production	P									3	x	3	3		
Production Engineering	PE		x												
Master and Quality	MQ		x										x	x	
Supplier Quality	SQ	1			1						1		3		
Supplier	S				1							1			
Product Line Maintenance	PLMBTS														
Integration and Verification	IV														

across a row shows all the information inputs you need to complete a task	**3**	meeting
looking down a column shows all the information outputs you will provide to other tasks	**2**	phone/mail
	1	document

Original Matrix for Frequency

		Cs	PM	MkD	SS	PSM	SD	MD	P	PE	MQ	SQ	S	PLM	IV
THE INPUT THEY USE COMES FROM		THE OUTPUT THEY GENERATE IS SENT TO													
Customers	Cs		2	3											
Product Management	PM			2			2	2	2			1			
Marketing Department	MkD														
Strategic Sourcing	SS					3		2			3		2		
Product Sourcing Management	PSM							1	x			3	3		
System Designers	SD							3							3
Mechanical Design	MD						1		3	2	2	1	3	x	3
Production	P									3	1	3	2		
Production Engineering	PE		x												
Master and Quality	MQ		x										x	x	
Supplier Quality	SQ	1			1						1		x		
Supplier	S				1							1			
Product Line Maintenance	PLMBTS														
Integration and Verification	IV														

across a row shows all the information inputs you need to complete a task	**3**	weekly or more
looking down a column shows all the information outputs you will provide to other tasks	**2**	monthly or less
	1	when needed

M1 Media Richness_1

THE OUTPUT THEY GENERATE IS SENT TO →
THE INPUT THEY USE COMES FROM ↓

		Cs	MkD	PM	SD	I&V	MD	P	SQ	S	PSM	SS	MQ	PE	PLM
Customers	Cs		1	1											
Marketing Department	MkD	1		1											
Product Management	PM	1	1		1		1	1	1						
System Designers	SD			1		1	1								
Integration and Verification	I&V				1		1								
Mechanical Design	MD			1	1	1		1	1	1	1	1	1	1	1
Production	P			1			1		1	1			1	1	
Supplier Quality	SQ	1						1		1	1	1	1		
Supplier	S						1	1	1		1	1			
Product Sourcing Management	PSM						1	1	1	1		1			
Strategic Sourcing	SS						1			1	1		1		
Master and Quality	MQ			1			1			1		1		1	1
Production Engineering	PE			1			1	1					1		
Product Line Maintenance	PLM						1								

M2 Media Richness_2

THE OUTPUT THEY GENERATE IS SENT TO →
THE INPUT THEY USE COMES FROM ↓

		SS	PSM	MD	P	PE	MQ	SQ	S	Cs	PM	MkD	SD	I&V	PLM
Strategic Sourcing	SS		1	1			1		1						
Product Sourcing Management	PSM	1		1				1	1						
Mechanical Design	MD	1	1		1	1	1		1		1		1	1	1
Production	P			1		1		1	1		1				
Production Engineering	PE			1	1										
Master and Quality	MQ	1		1											
Supplier Quality	SQ		1		1				1						
Supplier	S	1	1	1	1			1							
Customers	Cs										1	1			
Product Management	PM			1	1					1		1	1		
Marketing Department	MkD									1	1				
System Designers	SD			1							1			1	
Integration and Verification	I&V			1									1		
Product Line Maintenance	PLM			1											

M3 Frequency

THE OUTPUT THEY GENERATE IS SENT TO →

THE INPUT THEY USE COMES FROM ↓

		MQ	SS	PSM	SQ	P	PE	MD	SD	I&V	MkD	Cs	S	PLM	PM
Master and Quality	MQ		1												
Strategic Sourcing	SS	1		1											
Product Sourcing Management	PSM		1		1								1		
Supplier Quality	SQ			1		1									
Production	P				1		1	1							
Production Engineering	PE					1									
Mechanical Design	MD					1			1	1			1		
System Designers	SD							1		1					
Integration and Verification	I&V							1	1						
Marketing Department	MkD											1			
Customers	Cs										1				
Supplier	S			1				1							
Product Line Maintenance	PLM														
Product Management	PM														

M4 Intensity

THE OUTPUT THEY GENERATE IS SENT TO (columns) / THE INPUT THEY USE COMES FROM (rows)

		Cs	MkD	PM	SD	MD	SS	PSM	S	I&V	P	PE	MQ	SQ	PLM
Customers	Cs	0	9	6											
Marketing Department	MkD	9	0	6											
Product Management	PM	6	6	0	6	6					6			x	
System Designers	SD			6	0	9				9					
Mechanical Design	MD			6	9	0	6	3	9	9	9	6	6	1	x
Strategic Sourcing	SS					6	0	9	6				9		
Product Sourcing Management	PSM					3	9	0	9		x			9	
Supplier	S					9	6	9	0		6			3	
Integration and Verification	I&V				9	9				0					
Production	P			6		9			6		0	9	x	9	
Production Engineering	PE			x		6					9	0	x		
Master and Quality	MQ			x		6	9		x			x	0		x
Supplier Quality	SQ	1					1	9	3		9		1	0	
Product Line Maintenance	PLM					x									0

M5 Location

THE OUTPUT THEY GENERATE IS SENT TO (columns) / THE INPUT THEY USE COMES FROM (rows)

		A					**B**			**C**				**External**	
		PM	MkD	SS	I&V	PLM	PSM	SD	MD	PE	MQ	SQ	P	Cs	S
Product Management	PM	0	6					6	6			x	6	6	
Marketing Department	MkD	6	0											9	
Strategic Sourcing	SS			0			9		6		9				6
Integration and Verification	I&V				0			9	9						
Product Line Maintenance	PLM					0			x						
Product Sourcing Management	PSM			9			0		3			9	x		9
System Designers	SD	6			9			0	9						
Mechanical Design	MD	6		6	9	x	3	9	0	6	6	1	9		9
Production Engineering	PE	x							6	0			9		
Master and Quality	MQ	x		9		x			6		0				x
Supplier Quality	SQ			1			9				1	0	9	1	3
Production	P	6							9	9	x	9	0		6
Customers	Cs	6	9											0	
Supplier	S			6			9		9			3	6		0

M6 Matrix 6 - Role - Information

Role - Information
contents of the documents and meetings

Area	***Information***		Cs	PM	MkD	SS	PSM	SD	MD	P	PE	MQ	SQ	S	PLM	I&V
								ARE INVOLVED IN								
NEEDS AND REQUIREMENTS	Complete Product information			x	x											
	Product Information for the Customer		x		x											
	Needs		x	x	x											
	Interpretation of needs			x				x	x							
	General requirements			x				x	x							
	Specific requirements							x	x							x
	Examples of concepts			x					x							
	CAD								x					x		
	CAD								x	x						
DESIGN REVIEWS	**Reviews** - Design								x					x		
	Reviews - Design								x				x			
	Reviews - Design								x	x						
	Reviews - Design								x		x					
SUPPLIER MANAGEMENT	Supplier economic information					x								x		
	Preferred Supplier List					x			x							
	Supplier general info					x							x			
	Estimated volumes			x					x	x						
	Purchase order					x								x		
PRODUCTION	Production line understanding								x	x						
	Evaluation - Problems before delivery	HAVE THESE PARTICIPANTS		x					x	x		x				
	Production problems								x		x					
	Production error									x		x				
	Production line performance								x		x					
SUPPLIER	**Support** - Supplier Technical Problem					x			x				x			
	8 Disciplines								x				x	x		
	Evaluation - Supplier					x			x					x		
	Reviews - Quality								x				x	x		
	Evaluation - Product Quality					x							x			
	Support - Production Flow									x	x		x			
	Support - Quality (mature products)									x		x				
	Description - Product problems					x							x	x		
MANAGEMENT	Critical cutomer problems		x	x					x							
	Evaluation - Claims			x					x			x		x	x	
	Modified unit (modified after Supplier delivery)		x							x						
	Coordination plan								x				x			
	Deadlines			x					x				x			
	Product substitution information			x						x						
VERIFICATION	Verifications to perform							x	x							x
	Result of the verifications							x	x							x

Appendix G Interviewees

- The following table gathers the information about the people who has been contacted along the Thesis.
- They are listed by alphabetical order of their surnames.
- No names or commercial organisations outside Alpha are cited.
- The acronyms for the departments are exposed in the Acronyms and Terminology section, in the beginning of the report.

ID	Date	Role	Department		Location	Issue	Interview Round
1	30/04/2010	Operational Product Manager	PLM	Product Line Maintenance	A	Quality	Second round
2	15/04/2010	Product Manager	PM	Product Management	A	Quality	Second round
3	17/03/2010	Mechanical System Designer	MD	Mechanical Design	B	Interdepartmental information flow	First round
	17/05/2010	Mechanical System Designer	MD	Mechanical Design	B	Results validation	Validation meeting
4	16/03/2010	Quality Engineer	MQ	Master and Quality	C	Interdepartmental information flow	First round
5	28/04/2010	Operations developer		Project Office	B	New Lessons Learned Standard	Idea generation
6	08/04/2010	Consultant	MD	Mechanical Design	B	Requiremennts	Second round
	21/04/2010	Consultant	MD	Mechanical Design	B	Relation Design - Production	Second round
7	03/05/2010	Operational Product Manager	PLM	Product Line Maintenance	A	Premium Quality strategy	Second round
8	07/05/2010	PhD Candidate	--	Chalmers T.H.	Göteborg	Wiki/Engineering blogs	Idea generation
9	15/03/2010	Manager	SS	Strategic Sourcing	A	Interdepartmental information flow	First round
10	17/05/2010	Engineer	MD	Mechanical Design	B	Results validation	Validation meeting
11	09/04/2010	Quality Forum Responsible	PE	Production Engineering	C	Quality Forums	Second round
12	12/04/2010	Global Program Manager	S	Supplier	External	Relation Design - Supplier	Second round
13	26/04/2010	Senior Solution Manager	MkD	Marketing Department	A	Quality	Second round
14	11/06/2010	Consultant	MD	Mechanical Design	B	Trouble Report Closed Loop	Idea generation
15	17/05/2010	Line Manager	MD	Mechanical Design	B	Results validation	Validation meeting
	16/06/2010	Line Manager	MD	Mechanical Design	B	Results validation	Validation meeting
	29/06/2010	Line Manager	MD	Mechanical Design	B	Results validation	Validation meeting
16	12/02/2010	Operational Developer	MD	MD Operational Development	C	Premium Quality background	Thesis definition
	12/04/2010	Operational Developer	MD	MD Operational Development	C	Premium Quality/Closed Loop	Second round
	21/06/2010	Operational Developer	MD	MD Operational Development	C	LaPP process validation	Idea generation
17	12/04/2010	Local Program Manager	S	Supplier	External	Relation Design - Supplier	Second round
18	10/03/2010	Object Leader	MD	Mechanical Design	B	Interdepartmental information flow	First round
19	11/03/2010	Engineer	SQ	Supplier Quality	C	Interdepartmental information flow	First round
	07/04/2010	Engineer	SQ	Supplier Quality	C	Closed Loop	Second round
20	09/04/2010	Quality Forum Chairman	PE	Technical Support Group	C	Quality Forums	Second round
21	14/06/2010	Project Manager	MD	MD Project Office	A	Trouble Report Closed Loop	Idea generation
22	07/05/2010	Operational Developer	--	Project Office	A	Targets and strategies	Complementary input to interviews
	21/05/2010	Operational Developer	--	Project Office	A	Targets and strategies	Validation
23	12/04/2010	NPI Engineer	S	Supplier	External	Relation Design - Supplier	Second round
24	10/06/2010	PDM Specialist	--	Software	B	New Trouble Report Handling Platform	Idea generation
25	18/06/2010	Quality driver	MD	Mechanical Design	B	LaPP process validation	Idea generation
26	09/04/2010	Suport System Designer	SD	System Design	B	Requirements	Second round
27	01/03/2010	Quality driver	MD	Mechanical Design	B	Thesis definition	Thesis definition
	18/05/2010	Quality driver	MD	Mechanical Design	B	LaPP process concepts	Idea generation
	14/06/2010	Quality driver	MD	Mechanical Design	B	CIC meeting	Idea generation
	24/06/2010	Quality driver	MD	Mechanical Design	B	Results validation	Validation meeting
28	10/06/2010	Software developer	--	IT Consultancy Firm	Stockholm	New Trouble Report Handling Platform	Idea generation
29	19/04/2010	Repair Process Manager	--	Quality & Operational Development	C	Repair Process	Second round
30	23/03/2010	Line Manager	PE	Production Engineering	C	Interdepartmental information flow	First round
31	06/04/2010	Product Manager	PM	Product Management	A	Quality	Second round
32	18/03/2010	Manager	PSM	Product Sourcing Management	B	Interdepartmental information flow	First round
33	16/03/2010	Project Manager	MQ	Master and Quality	C	Interdepartmental information flow	First round
34	15/03/2010	Manager	SS	Strategic Sourcing	A	Interdepartmental information flow	First round
35	04/05/2010	PhD Candidate	--	Chalmers T.H.	Göteborg	Lean Product Development	Idea generation
36	17/06/2010	Mechanical Design Manager	MD	Mechanical Design	B	LaPP process validation	Idea generation
37	15/03/2010	Manager	SQ	Supplier Quality	C	Interdepartmental information flow	First round
38	01/03/2010	Quality driver	MD	Mechanical Design	B	Thesis definition	Thesis definition
	18/05/2010	Quality driver	MD	Mechanical Design	B	LaPP process concepts	Idea generation
39	12/03/2010	Mechanical System Designer	MD	Mechanical Design	B	Interdepartmental information flow	First round
	17/05/2010	Mechanical System Designer	MD	Mechanical Design	B	Results validation	Validation meeting
40	23/04/2010	Engineering Manager	Cs	Customer	External	Relation Alpha - Customer	Second round
41	14/04/2010	Claims Process Manager	--	Quality & Operational Development	C	Claims Process	Second round
42	14/04/2010	Manager- R&D	I&V	Integration and Verification	A	Relation Design - Verification	Second round
43	15/04/2010	Program Manager	S	Supplier	External	Relation Design - Supplier	Second round

Appendix H Interview Guide

- This Appendix includes the template of Interview Guide used during the first round of interviews.

Interview guide

First Round

Objective

- Understand and describe the Information flow.
- Identify key issues about the information transferred between departments at an overview level.

Personal Info

- Department:
- Role (Manager, Object Leader, Designer…):
- Area of responsibility:
- Time working at Alpha:

Quality

- What do you know about Premium quality?
- What is quality to you?
- Current problems with quality?
- How can quality be achieved according to you?
- How do you work to include the quality of your products?

Relation with the procedures

- Do you follow strictly what the process states?
- Do you think that the people in the department follow it?
- Regarding information transfer during a project; do you know what your role is supposed to transfer to other roles and departments?
- Are the procedures easy to improve? Do you feel committed to it?
- Do you think that better procedures would generate better quality?

Department Relations

Relation with Suppliers

- How does it work right now?
    - Mean, when, frequency, locations, type of information…
- What is not working? Problems?
- Improvements?

Relation with Product Management

- How does it work right now?
    - Mean, when, frequency, locations, type of information…
- What is not working? Problems?
- Improvements?

Relation with Production

- How does it work right now?
    - Mean, when, frequency, locations, type of information…
- What is not working? Problems?
- Improvements?

Relation with Strategic Sourcing

- How does it work right now?
    - Mean, when, frequency, locations, type of information…
- What is not working? Problems?
- Improvements?

Relation with Mechanical Design

- How does it work right now?
    - Mean, when, frequency, locations, type of information…
- What is not working? Problems?
- Improvements?

Closed loop

- Do you collect information at the end of a project?
    - How? Personal experiences, thoughts, forms, databases…
- What do you do with this information afterwards?
- Do you use information from older projects?
- Does the current process help in these issues?

About this questionnaire

- Is there anything else you want to add?
- What would you change of this questionnaire?
- Do you have any contacts that you think would be interested on collaborating in this study?

Appendix I   Matlab Code

```
function [Best_DSM, nonzero_cost_history] = findOptimalDSM(inputDSM)

%***********************************************************************
% Outputs:
%   Best_DSM - matrix containing the lowest cost DSM obtained over the
%              "number of iterations"
%   nonzero_cost_history - vector containing cost history over the
%                          completer number of iterations
% %*********************************************************************
% Parameter stating how many iterations should be performed
number_of_iterations = 1000;

% ************************Setting up DSMs***************************
% Parameter stating the size of the DSM
DSM_size = 14;

% Assigning input matrix to the 'DSM' parameter, which is put into the
% run_Cluster_B.m script file
DSM = inputDSM;

% DSMLABEL - String vector containing the row and column labels for the DSM
DSMLABEL = cell(DSM_size,1);
DSMLABEL{1,1} = 'Cs';
DSMLABEL{2,1} = 'PM';
DSMLABEL{3,1} = 'MkD';
DSMLABEL{4,1} = 'SS';
DSMLABEL{5,1} = 'PSM';
DSMLABEL{6,1} = 'SD';
DSMLABEL{7,1} = 'MD';
DSMLABEL{8,1} = 'P';
DSMLABEL{9,1} = 'PE';
DSMLABEL{10,1} = 'MQ';
DSMLABEL{11,1} = 'SQ';
DSMLABEL{12,1} = 'S';
DSMLABEL{13,1} = 'PLM';
DSMLABEL{14,1} = 'IV';

extract_elements = [ ];
% **********************************************************************
```

```
% ****************Looping the  clustering Algorithm*******************
% Iterate clustering algorithm accordin to number_of_iterations
run_cluster_B;
close all;
Best_totalt_coord_cost = total_coord_cost;
Best_DSM = New_DSM_matrix;
Best_New_DSM_labels = New_DSM_labels;
nonzero_cost_history = [total_coord_cost(total_coord_cost~=0)];%=
[total_coord_cost];

for i=1:number_of_iterations
    run_cluster_B;
    close all;
    if Best_totalt_coord_cost > total_coord_cost;
        Best_totalt_coord_cost = total_coord_cost;
        Best_DSM = New_DSM_matrix;
        Best_New_DSM_labels = New_DSM_labels;
    end
i;
nonzero_cost_history = [nonzero_cost_history,
total_coord_cost(total_coord_cost~=0)];
Best_totalt_coord_cost;

end

% Show DSM_labels according to the clustered DSM in the Comman Window
Best_New_DSM_labels

% Add ones to the clustered DSM along the main diagonal
Best_DSM = place_diag(Best_DSM, 1);

% Show cost_history vector in the Command Window
Best_totalt_coord_cost = min(nonzero_cost_history)

% Plot Clustered DSM
graph_matrix(Best_DSM,'Element','Element','Best_DSM', Best_New_DSM_labels,
Best_New_DSM_labels, 1, Cluster_matrix);
figure;
plot([1:number_of_iterations+1], nonzero_cost_history);
end
```