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Ward trolley product development plan for the health care industry and market survey on its usability in the Nordic Countries

Case: Innopart Ltd

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Seinäjoen ammattikorkeakoulu
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Thesis Abstract

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Title of thesis: Ward trolley product development plan for the health care industry and market survey on its usability in Nordic Countries

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The thesis is about a product development plan for a ward trolley made based on the requirements of hospitals in Finland. Moreover, the thesis includes a market study of its usability in the Nordic countries. The study for the product development plan was carried out in five Finnish central hospitals: Helsinki, Joensuu, Rovaniemi, Seinäjoki and Vaasa. It was conducted by face-to-face conversations, telephone interviews and a survey template. To ensure that everything was taken into consideration, the development plan was made based on a customer needs analysis. This process includes six phases, starting with defining and analysing customer needs, along with gathering information about competitors. Based on this information, a House of Quality matrix was made, where importance ratings were calculated for each feature. Thus, the most important features for a ward trolley and how they interact could be analysed. In turn, the market study in the Nordic countries was done by snowball sampling, which resulted in contacts with biomedical laboratory scientist associations in Denmark, Finland, Iceland, Norway and Sweden. In Sweden, information was also obtained from nurses. The survey was sent by email. The results for the product development plan are extensive enough and, therefore, the plan be transferred to the designer. The market study

Keywords: Biomedical laboratory association, customer needs analysis, House of Quality, market research, product development, ward trolley

in the Nordic countries appointed the target group and the market situation. This thesis is classified; therefore, specific details are left out from the abstract.

SEINÄJOEN AMMATTIKORKEAKOULU

Opinnäytetyön tiivistelmä

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Opinnäytetyö sisältää osastovaunun tuotekehityssuunnitelman, joka on tehty sairaaloiden tarpeiden pohjalta Suomessa. Lisäksi opinnäytetyö sisältää markkinatutkimuksen osastovaunun käytettävyydestä Pohjoismaissa. Yhteistyökumppaneina ovat olleet viisi keskussairalaa seuraavilta paikkakunnilta: Helsinki, Joensuu, Rovaniemi, Seinäjoki ja Vaasa. Tutkimus on toteutettu keskusteluilla, puhelinhaastatteluilla ja tutkimuslomaketta käyttäen. Suunnitelma on tehty noudattaen “customer need analysis” -vaiheita varmistaakseen, että kaikki oleelliset vaiheet ovat otettu huomioon tuotekehityksessä. Tämä prosessi koostuu kuudesta kohdasta alkaen asiakkaiden tarpeiden määrittelyllä, jonka jälkeen kerätään tietoa kilpailijoista. Saatujen tietojen pohjalta on tehty Laaduntalo-matriisi, jossa tärkeysasteet on laskettu jokaiselle ominaisuudelle. Täten osastovaunun tärkeimmät ominaisuudet ja näiden välisiä riippuvuuksia voi analysoida. Pohjoismaiden markkinatutkimus puolestaan on tehty käyttäen lumipallomenetelmää. Tuloksena otettiin yhteyttä bioanalyytikkoliittoihin Tanskassa, Suomessa, Islannissa, Norjassa ja Ruotsissa. Ruotsista tietoa kerättiin myös hoitajilta, joille lähetettiin kysely sähköpostilla. Osastovaunun tuotekehityssuunnitelman tulokset ovat tarpeeksi kattavia, joten se voidaan siirtää suunnittelijalle. Markkinatutkimus puolestaan osoitti kohderyhmät ja

Avainsanat: Bioanalyytikkoliitto, asiakastarpeiden kartoitus, Laaduntalo, markkinatutkimus, osastovaunu, tuotekehitys

markkinatilanteen. Opinnäytetyön tutkimusosio on salainen, joten tarkemmat tiedot on jätetty tiivistelmästä pois.

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Abbreviations

ABS plastic	ABS is a terpolymer made by polymerizing styrene and acrylonitrile in the presence of polybutadiene
CEO	A chief executive officer describes the position of the most senior corporate officer or administrator in charge of managing a for-profit organization.
In-depth interviews	an in-depth interviews is designed to reveal the underlying motives of the interviewee's attitudes, behavior, and perceptions.
Mature Product	The product will reach the upper bounds of its demand cycle and further spending on advertising will have little to no effect on increasing demand.
Observation	Observational research (or field research) is a type of correlational (i.e., non-experimental) research in which a researcher observes ongoing behavior.
QFD	Quality Function Deployment also called House of Quality is a matrix that can be done to improve product development process
SWOT-analysis	is a structured planning method used to evaluate the strengths, weaknesses, opportunities and threats involved in a project or other business case.
The voice of the customer	A term to describe stated and unstated customer needs or requirements.

Ward trolley	Used in bedside rounds in hospitals.

1 INTRODUCTION

The thesis consists of two parts: firstly, a product development plan for ward trolleys and, secondly, a market study of the usability of the trolley in the Nordic countries. The purpose of the study is to conduct wide and feasible study of a ward trolley for Innopart Ltd in order to give a solution for hospitals' needs. Moreover, exploring if the new ward trolley may have a market in the Nordic countries. The idea for this thesis came from a biomedical laboratory technologist, whose opinion was that currently there was no proper ward trolley in the market. Therefore, this proposition is made based on hospitals' suggestions for development. Consequently, deep research is made for hospitals in Finland. In the second part, survey is conducted among nurses in Sweden and biomedical laboratory scientists associations in Nordic countries. Also, some hospital partners in Finland, who have been part of this work, will have prototypes in test use.

1.1 Background of the Company

Innopart Ltd is a Finnish company founded in 2010 by two men, Kimmo Niska and Petri Hirvelä. The company provides laboratory furniture for hospitals and sport equipment racks for consumers. In 2014, Niska bought Hirvelä's share of the company and became the sole owner. A company called SteelComp Ltd is the manufacturer of these products, while Innopart Ltd is a sales and marketing company. SteelComp is owned by Kimmo Niska (50%) and Innopart Ltd. (50%).

1.2 Study problem and methodology

The study problem was to define hospital personnel requirements with regard to the ward trolley. The methodology used in this thesis was qualitative research, in order to give freedom for the respondents to give honest and independent answers. The survey is based on a deep understanding between the author and the respondents. This is done through face-to-face conversations, telephone interviews and a structured survey template sent by email. Questions in the survey

template are formed to give a respondent the opportunity to say his/her own opinion about the topic. To be more precise, the survey includes questions about ward trolley's features and comparison of the ward trolleys which are currently in the market. The language used in the product development project has been Finnish. The market survey in the Nordic countries was done by email. The language used in the survey is mainly English; however, for the hospital employees in Sweden, Swedish has been the common language between the author and respondents.

2 WHAT IS PRODUCT DEVELOPMENT?

According to Rouse (2014), product development is the process of creating, designing, and marketing new products or services to benefit customers. New product development can be referred to as development of systematic methods for guiding all the processes involved in getting a new product to market. Product development contains either improving an existing product or its performance, or developing a new product and targeting it to a particular market segment or segments.

2.1 Process of product development

Figure 1. Product development process (Minato 2015).

The figure above shows the process of product development. According to Rantamaki (2001), usually a new idea comes from a problem which leads into an innovation, thereby solving the problem with a new product or service, or by developing an old product or service. In the implementation phase it is crucial to explore markets, define customer needs, and know the technology and competitors. A company also needs to define their place in the market. They can be a pioneer, a follower, an applier or an imitator.

Linton points out that the gathered information in the implementation phase helps to put together a business case, budget and project plan for developing a new

product with commercial potential. In this phase, engineers start to design technical features. However, the marketing department should monitor designs to ensure that the team continues to focus on developing features that are important to customers. If the costs of development increase, the engineers may have to prioritize work on new features and revise the specification.

According to Linton, testing the new product in the market before it moves into manufacturing is important. Creating a prototype and asking selected customers for feedback can help to minimize the risk of costly mistakes. Another possibility is to discuss the concept with customers and use their opinions to make any necessary adjustments to the final specification. Moreover, an internal review should be made to ensure that the project continues to meet its potential customer's requirements. If the review reveals serious deficiencies, the team needs to make changes or stop the project before committing further resources.

Linton points out that if the product reaches the launching phase, it needs to be planned carefully. Briefing the sales and customer service team on the new product, in order to make sure that they are ready to present the benefits to customers and handle inquiries, is a priority. Furthermore, preparing product advertisements, website pages, press releases and e-mail communications are necessary.

2.2 Meaning of product development

Based on a web article "New product development" product development is a necessity for all companies. It helps to stay ahead of the competition, improve quality, and meet changes of customer needs. Thus, companies need to be flexible and fast. If a company doesn't develop new products someone else will and takes away customers. No business can continue to offer the same unchanged product, by doing so sales would decrease, as well as profits. The Figure below indicates some reasons why product development is important for sales and profit.

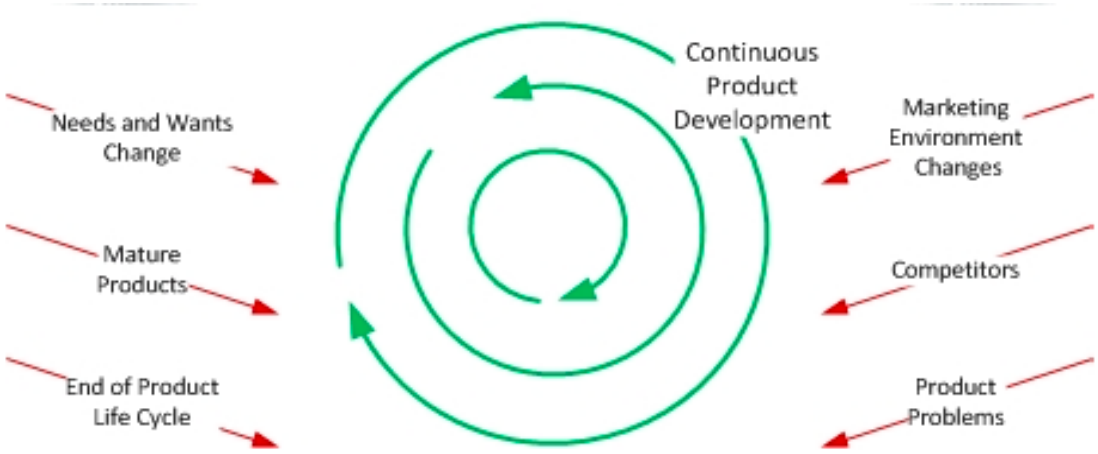

Figure 2. Continuous product development (New product development]).

2.3 Errors in product development

Cagan (2006), points out bad products are everywhere – products that are not useful, do not work right or properly, are too difficult to figure out, or take forever to sell. In order to have a successful product, many things have to go right. Still, there are some things that go wrong often and are too damaging that they are clearly causing the majority of bad products.

Cagan (2006), lists the most common mistakes that occur in the product development process:

1. Confusing customer requirements with product requirements.

Product teams often look to the marketing team, or the sales department, or the customer to help them define the developed product. For example, if it is a custom product, it may be fine to have the marketing or sales team define the product. Difficulty in this approach is that it seldom delivers innovative products that meet the needs of a wide range of customers. Marketing people are expected to know customers' requirements, since they are communicating with the customers. Nevertheless, this line of communication isn't the most suitable for several reasons.

First, customers don’t necessarily know or recognize their needs because it is difficult for them to articulate a specific product solution without first seeing a prototype. Secondly, customers don’t know what is possible. Moreover, they do not have the time or knowledge to stay alongside of the many developments in technology that may influence product solutions. The third reason is that customers cannot visualize the whole range of product needs and opportunities. Furthermore, they probably don’t have enough time to think of how their own needs may overlap with the needs of others.

2. Confusing innovation with value

There are countless products on the market today only because it became possible to create them and not because they would have solved a real problem. More likely, engineers are not motivated by the same things as other members of the product team. The technical challenge itself and the opportunity to learn and use different technologies, are factors that motivate engineers; not solving problems. However, if the engineering team is provided with a clear vision and product strategy, along with direct understanding of customer problems, they can often come up with valuable breakthrough products.

3. Confusing yourself with your customer

Very often product teams may think that they are more like their target customer than they really are. This kind of confused thinking has many negative consequences and the most common one is an unusable product. The product may make perfect sense to its creators, but its benefits are totally lost on the customers for whom it is intended. In order to stay honest and on track, organizations should put their products in front of their target customers and carefully consider how they respond. After all, only the customers’ opinions of the product are relevant. Many of today’s products are unusable because the product is poorly designed and was not tested for usability. The use of prototypes during usability testing can help to ensure that the product is still usable and desirable.

4. Confusing the customer with the user

Making a distinction between customers and users is relevant due to the fact that these groups typically have very different kinds of needs. However, too often the product team is exposed only to the customers — that is, the buyers or economic decision makers. While these customers represent the needs of the actual users, it is still crucial that product creators have a first-hand understanding of the people who will be using the product. The technique of profiling the user can help to address this issue early in the process.

5. Confusing features with benefits

A product team can easily become obsessed with the specifics of the features in a product and put aside the benefits that those features provide. The product's value proposition should be crystal clear, simple and interesting; but it should provide the benefits, not the features. In order to make this happen, an organization must have a deep understanding of its target market. On the other hand, the people in that market must discover that the product solves a problem that is real to them.

6. Confusing building the right product with building the product right

Doing a good job of building a product is often correlated with process goals such as scheduling, budget and quality. These benchmarks correspond to building the product right, which means that the product is reliable and performs its functions as required. Unfortunately, all this effort is for naught if the product has no value to the customer. The product team doesn't only need to build the product right but also build the right product.

Requirements are the base of product development. Culture, management and individuals can all cause bad requirements which in turn, causes mistakes in product development. The figure below (3) demonstrates how writing requirements can be defaulted and why writing product requirements well is important.

Culture	Management	Individual
Impatience with time	People don't have clear understanding of what the project is about	Employee doesn't know what to do when writing requirements
Acceptance of mistakes	People don't know how to write requirements	No training for the job
Urge to improvise when a problem occur	Expecting that reviews will catch possible problems	Can't write good requirements
Bias toward making assumptions	Nothing can be done about bad requirements	Doesn't have necessary information
		Doesn't understand the customer needs
		Doesn't understand the importance of the requirements
		Doesn't understand the impact of the requirements

Figure 3. Requirements in product development (Hooks & Farry 2001, 16–28).

3 ERGONOMY AND QUALITY IN PRODUCT FEATURES

3.1 Concerning ergonomics in product development

Based on Rouse (2007), ergonomics is the science of refining the design of products to optimize them for human use. Human characteristics, such as height, weight, and proportions are considered, as well as information about human hearing, sight, temperature and preferences.

According to Väyrynen, Nevala and Päivinen (2004, 15–16), the goal for ergonomics is to achieve the best possible compatibility between a product and a user in that task where the product is meant to be used. Utilizing principles of ergonomics are, for example, the following:

- Considering ergonomic principles in order to decrease mental and physical stress. These principles also improve human performance and liability of activities and thereby, decrease the probability of mistakes.
- Considering the measurements, power and positions, and the extent of the movements of a user group.
- Controls, signaling and information display devices are planned in a way that they are easy to understand. Interaction between the user and the product or machine is unambiguous.
- Avoiding loading positions and movements.
- Avoiding noise, vibration and heat.

According to Väyrynen et al. (2004, 269), ergonomics and the availability of technical excellence should benefit users and manufacturers as follows:

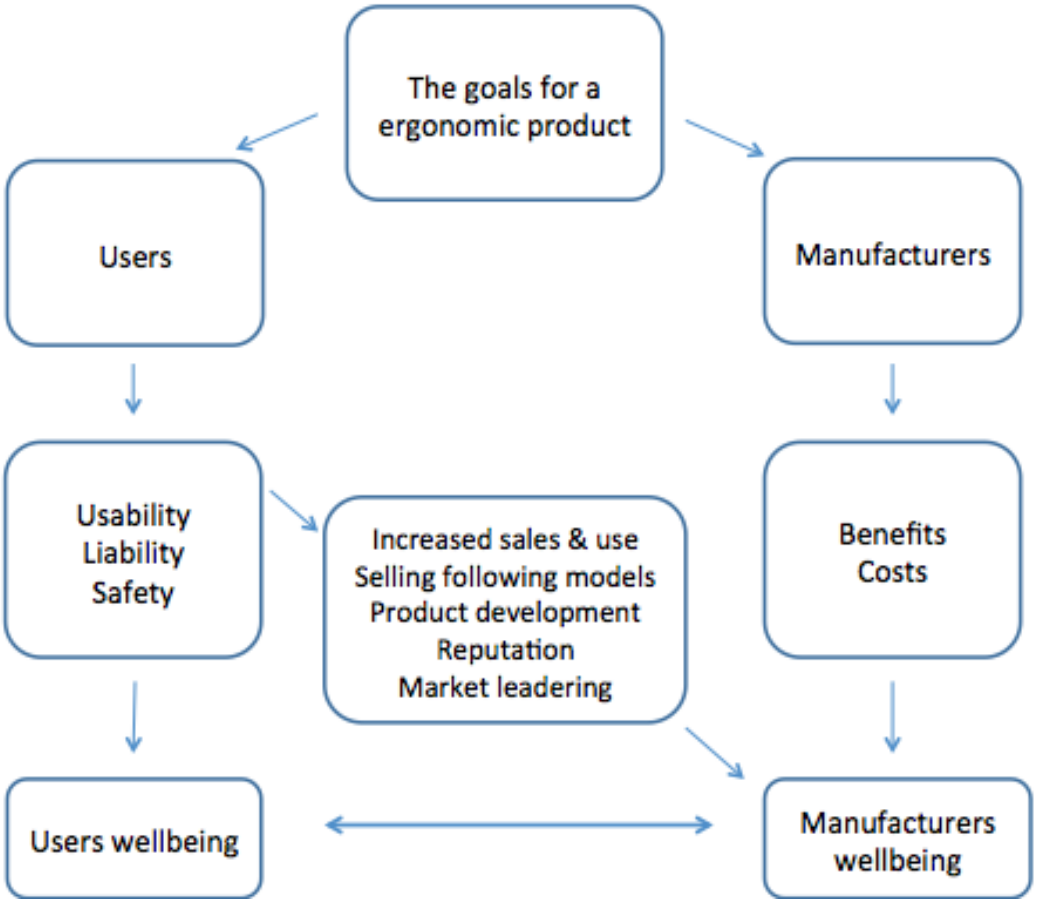

Figure 4. Benefits for users and manufactures of ergonomic products (Väyrynen et al. 2004, 269).

3.1.1 Anthropometric features

Ryan (2011), states that anthropometrics means the study of the human body and its movement, usually defined as research into measurements relating to people. It also contains collecting statistics or measurements relevant to the human body, called Anthropometric Data. Furthermore, anthropometric data is used by designers and architects.

Väyrynen et al. (2004, 57), have divided anthropometric measurements into four segments.

- Linear, for example width, height and length.
- Angular measurements, for example bending and twisting.
- Circumferences, for example head, neck, chest and waist.

- Force measurements, for example clamping force and mass.

Väyrynen et al. (2004, 58) also state that in designing, the measurements above can be used either according to medium size, extreme size or according to the range.

1. Medium sizes are used in public places like busses. The problem is that no one is exactly the medium size.

2. Extreme sizes are used mostly in the shoe and clothing industry. Almost everyone will get their own size.

3. Range of the size is the most common method. Typically, normal distribution is that 5 percentage points represent the shortest person and 95 percentage points represent the tallest person. Therefore, it can be assumed that, for example, adjustability guarantees that 90% of the users can use the product reasonably well.

3.2 Designing quality products

Designing, manufacturing and developing a quality product requires ergonomic and availability expertise. Total quality management, ergonomics and risk controlling aspects are highly synergistic. The relationship between quality, ergonomics, safety and profitability can be illustrated as follows:

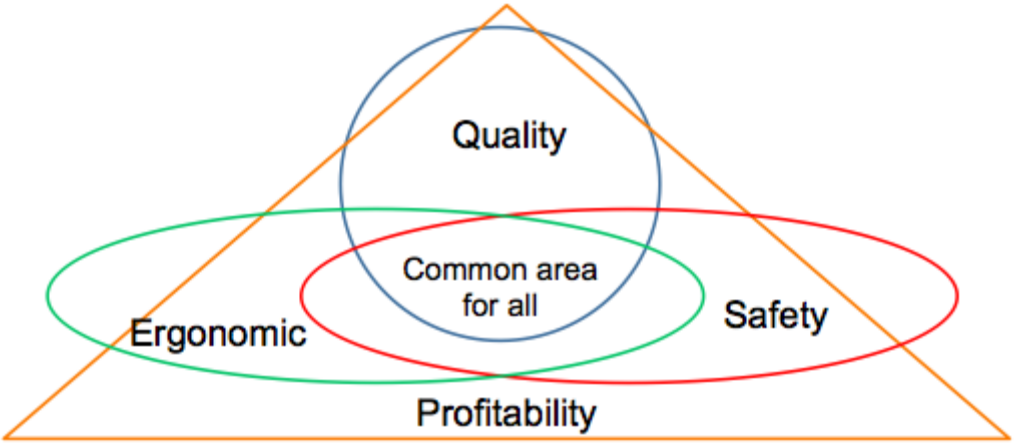

Figure 5. The relationship between quality, ergonomics, safety and profitability (Väyrynen et al. 2004, 40).

What are the requirements for a good product? According to Väyrynen et al. (2004, 214), there is no settlement option which would be absolutely the best. The solution depends on valuations. The designer has to evaluate the qualifications and decide which are the most important for the customers. The overall quality goal can be divided as follows:

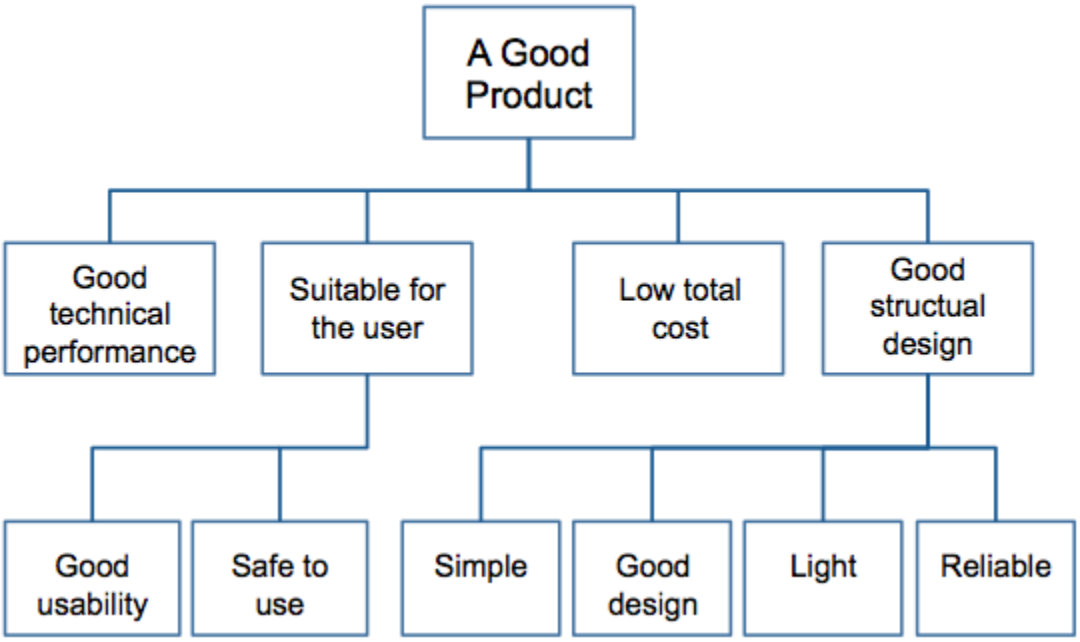

Figure 6. Overall quality goal (Väyrynen et al. 2004, 214).

According to a web page Kavon International (2011), the idea for total quality management came in the late 1920s by Walter A. Shewhart, but in the 1950s W. Edwards Deming popularized this theory.

Arveson (1998), points out that Deming proposed that business processes should be measured and analyzed by identifying sources of variations that are causing the change of products from customer requirements. According to Deming, business processes should be placed in a continuous feedback loop. Thereby, managers can identify and change the parts of the process that need improvement. Deming created a diagram to illustrate this continuous process, commonly known as the PDCA cycle.

- PLAN: Designing, observing or revising a process segment in order to improve results.
- DO: Implementing a solution and measuring its performance.
- CHECK: Verifying the improvement by measuring and reporting the results to decision makers.
- ACT: Deciding on needed changes in order to improve the process.

Deming's PDCA cycle can be demonstrated in the table below:

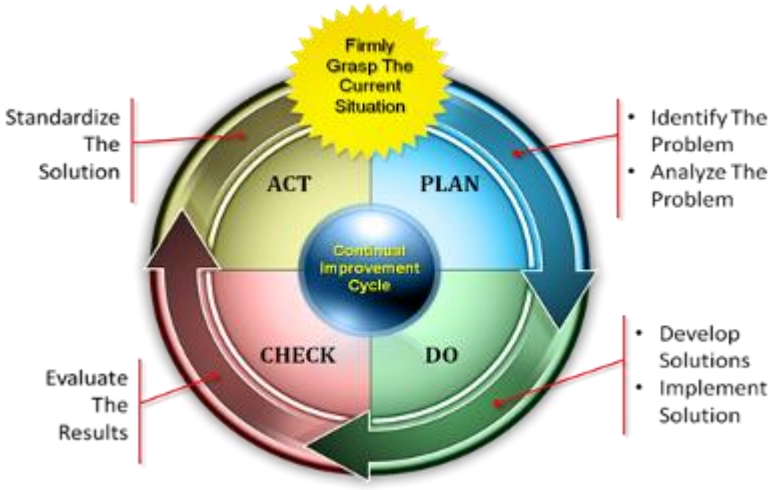

Figure 7. Phases of Deming’s PDCA cycle (Arveson 1998).

4 CUSTOMER REQUIREMENTS

Kärkkäinen et al. (2000, 6), state that product development can be divided roughly into two segments; either designer oriented approach or customer oriented approach.

According to Kärkkäinen et al. (2000, 6), an idea of a designer might be useful and successful but in practice, however, as often happens, that designer is certain about developing the product or service, but in the end it doesn't please customers. Therefore, a better starting point for product development is to clarify customer needs and form a picture of their needs in order to design a product or a service which is based on these needs. Differences between a designer oriented approach (left side) and customer oriented approach (right side) can be illustrated as follows:

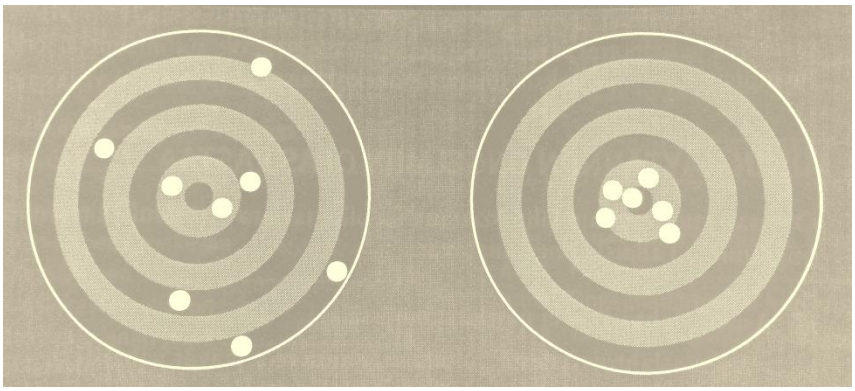

Figure 8. Designer oriented and customer oriented approach (Kärkkäinen et al. 2000, 6).

4.1 Customer needs analysis

Kärkkäinen et al. (2000, 17), propose that customer needs should guide a company's development, especially in the product development phase. This can be ensured by following a customer needs analysis process. This process contains six phases which are listed below:

1. Defining the starting point

2. Gathering information of customer needs
3. Analyzing the information of customer needs
4. Gathering information of competitors
5. Setting the goals for the product
6. Guiding in order to achieve the goals.

The process starts with defining a starting point. In this phase, the following questions are important to fulfill:

Who are customers?

- Who are competitors?
- Which features will make the company competitive?
- How wide is the development process; creating a new product or improving the old one?
- What the company knows about the competitors and what tools are used in order to find out more information?

The second phase is based on defining customer needs. Defining these needs is done by research. There are two types of research methods: quantitative and qualitative.

According to the online article Quantitative and qualitative research (2009), quantitative research focuses in counting and classifying features and constructing statistical models and figures to explain what is observed. Only measurable data are being gathered and analyzed in quantitative research.

The web article Quantitative and qualitative research (2009), also states that qualitative research, on the other hand, focuses more on gathering mainly verbal data rather than measurements. Gathered information is then analyzed in an explanatory, subjective, impressionistic or even diagnostic manner. The primary aim of qualitative research is to understand the customer by providing a complete,

detailed description of the research topic. Qualitative research is usually more exploratory in nature. Qualitative research is ideal for the earlier phases of research projects, while for the latter part of the research project, quantitative research is highly recommended. Quantitative research provides the researcher a clearer picture of what to expect in the research, when compared to qualitative research.

Based on the web article Quantitative and qualitative research (2009), when using qualitative research, the researcher can use various data-gathering strategies, depending upon the thrust or approach applied to the research. Examples of data-gathering strategies used in qualitative research are individual in-depth interviews, structured and non-structured interviews, focus groups, narratives, content or documentary analysis, participant observation and archival research. On the other hand, quantitative research makes use of tools such as questionnaires, surveys, measurements and other equipment to collect numerical or measurable data.

According to Kärkkäinen et al (2000, 43–44), the third phase in the process is to interpret and analyze customer requirements. Usually a company knows only part of the customers' needs. Behind the known needs might be needs like; the customer considers something self-evident, the customer doesn't recognize the present need or any needs which may occur in the future.

Based on Kärkäinen et al (2000, 49–51), defining the company's competitive situation is the fourth phase. This includes competitor and goal analysis. Analysis is done through comparison by a customer. This helps the company to get information on the most important features in the product. Difficulties in this phase are that the company should already have a product and the customer should have experience with the product. Moreover, the customer and the company need to know some competitors.

According to Kärkkäinen et al. (2000, 52–55), Quality Function Deployment is usually used in the fifth phase of the process, which is setting goals for the product. This QFD is also called House of Quality.

4.2 Quality Function Deployment

Turunen (1992, 19–20), propose that QFD is a tool that was born in Japan during the middle of the 1960s, and to Finland the method came in 1990. According to Kärkkäinen et al. (2000, 52–53), and Crow (2014), QFD is a structured approach in defining customer needs or requirements and translating those into specific plans to produce products which meet customers' needs. The figure below illustrates this approach:

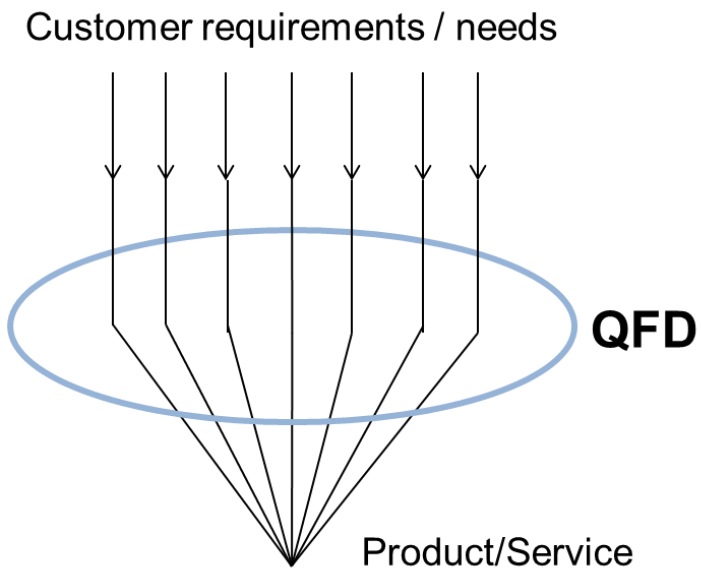

Figure 9. Quality Function Deployment approach (Turunen 1992, 23).

Crow (2014) and Kammonen (2012), propose that the basic QFD methodology contains four basic phases that occur over the course of the product development process. During each phase one or more matrices are prepared in order to help plan and communicate critical product and process planning and design information.

Turunen (1992, 20–21), refers to L.P. Sullivan (1986), when proposing that these phases are product designing, part planning, process planning and quality manufacturing control. Very often companies are doing only phase one. The phases are dependent on each other and therefore, done in a linear timeline as follows:

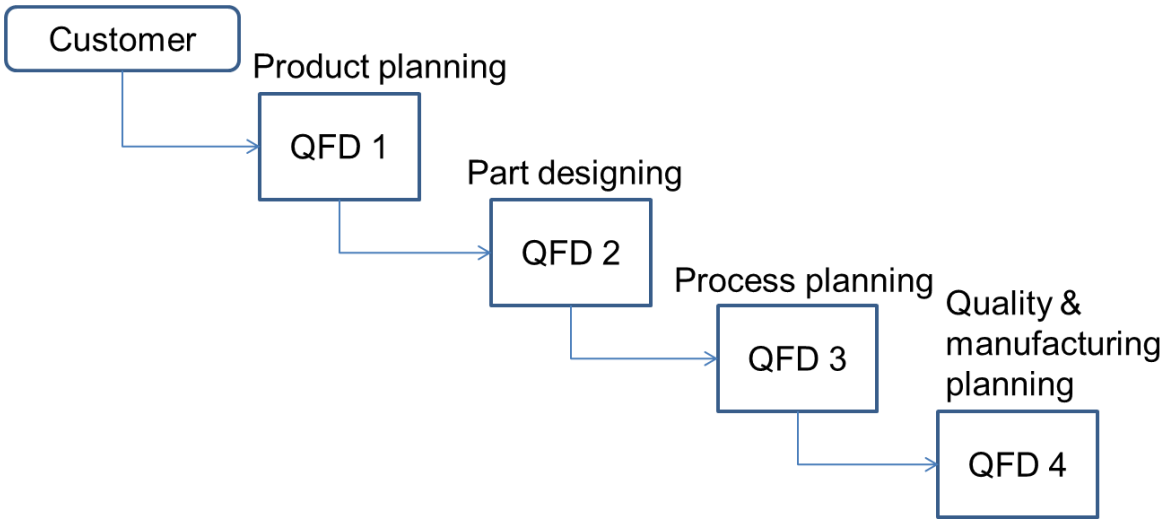

Figure 10. The four phases of Quality Function Deployment (Turunen 1992, 21).

In this thesis, the QFD phase 1 is explained more precisely due to the reason that the House of Quality is filled in the empirical part. Phases 2, 3 and 4 are explained in a cursory way because these phases are left out of this thesis in the empirical part.

Benefits of QFD

According to Turunen (1992, 22), QFD is relatively simple tool but usage of QFD requires a huge amount of knowledge processing. Therefore, there are many companies who do not use this method. On the other hand, many companies in Japan, USA and also in Europe have realized the huge benefits of this tool and the use of this method is increasing.

Turunen (1992, 22), propose that QFD does not only save money, but also time. The practice has shown that this method saves development time 30–50 percent. Moreover, it decreases occurring problems in manufacturing. The costs of mistakes decrease due to the fact that mistakes are noticed in an earlier stage.

4.2.1 Product planning

The first phase in product planning is to gather customers' needs and requirements. According to Crow (2014), the voice of the customer can be captured in a variety of ways:

- Direct discussion or interviews
- Surveys
- Focus groups
- Customer specifications
- Observation
- Warranty data
- Field reports etc.

After gaining an understanding of customer needs, it is summarized in a product planning matrix or "house of quality".

House of Quality is shown below:

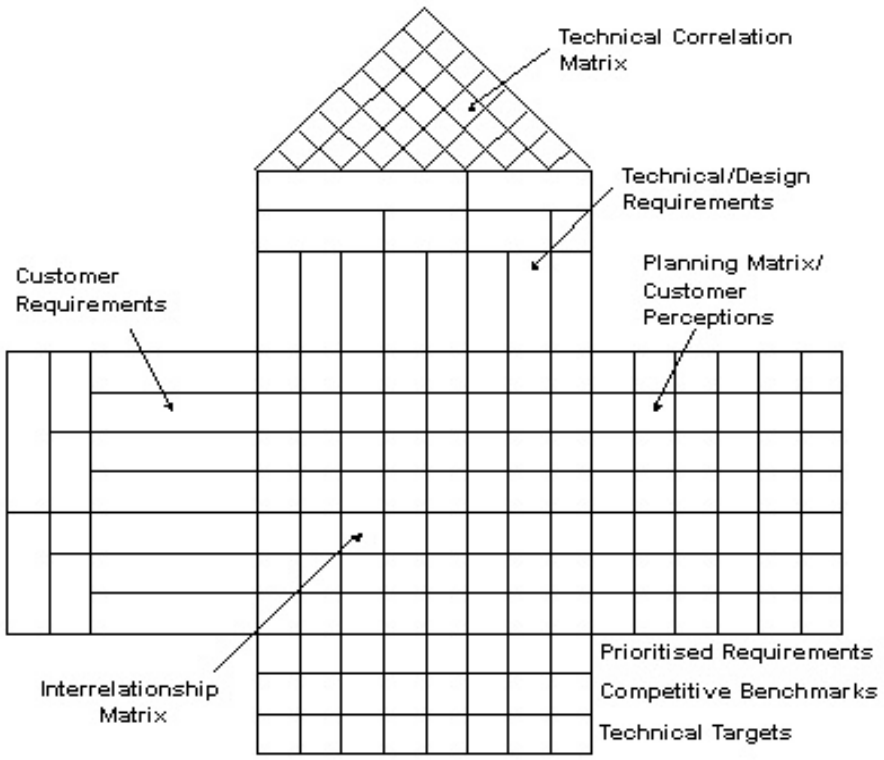

Figure 11. The House of Quality matrix (Tapke

Crow (2014), divides this product planning matrix into ten points that need to be fulfilled. The sequence of these ten points in preparing the product planning matrix is as follows:

1. Customer needs or requirements are divided into customer priorities using a 1 to 5 rating. Priorities can be developed by using ranking techniques and paired comparisons.

2. Evaluating prior generation products against competitive products by using surveys, customer meetings or focus groups to get feedback. Identifying price points and market segments for products under evaluation. Improvement areas can be identified by warranty, service, reliability, and customer complaint problems.

3. Organizing product requirements or technical characteristics into categories based on customer requirements. Characteristics should be meaningful,

measurable and global. Moreover, they should be stated in a way to avoid implying a particular technical solution in order not to constrain designers.

4. Illustrating relationships between customer requirements and product requirements or technical characteristics by using a scale of 9-3-1-0 (9 being very strong).

5. Developing a technical evaluation of the current product and competitive products. Get access to competitive products in order to perform product or technical benchmarking. Performing this evaluation based on the defined product requirements or technical characteristics.

6. Developing preliminary target values for product requirements or technical characteristics.

7. Determining potential positive and negative interactions between product requirements or technical characteristics by using symbols for strong or medium, positive or negative relationships.

8. Calculating importance ratings. Assigning a weighting factor to relationship symbols 9-3-1-0, multiplying the customer importance rating by the weighting factor in each box of the matrix and then adding the resulting products in each column.

9. Developing a difficulty rating (5, 7, 9 point scale, nine being very difficult and risky) for each product requirement or technical characteristic. Considering following factors:

    - Technology maturity
    - Personnel technical qualifications
    - Business risk
    - Manufacturing capability
    - Supplier/subcontractor capability
    - Cost and schedule

10. Analyzing the matrix and finalizing the product development strategy, target values and product plans. Determining focus areas and other required actions.

4.2.2 Part designing

According to Turunen (1992, 33), in the second QFD phase the product requirements are changed into part specifications. This phase can be divided into four parts:

1. Choosing the concept for the parts
2. Choosing the crucial parts
3. Parameters of the crucial parts
4. Choosing parts for further processing

4.2.3 Process designing and quality & manufacturing control

According to Turunen (1992), process designing is a generic name to all activities where a product is refined. Moreover based on Crow (2014), communication between engineering and manufacturing is highlighted and compromises can be made as appropriate in order to achieve mutual goals based on the customer needs. Additional matrices can be done to support process control, quality control, set-up, equipment maintenance and testing.

Crow (2014), proposes that the result of the planning and decision-making is that manufacturing focuses on the critical processes, characteristics and dimensions in order to have a significant effect on producing a product or a service that meets customers' needs. Moreover, there should be a clear trail from customer needs to the design and manufacturing decisions in order to satisfy those customer needs. Disagreements over what is important at each stage of the development process should be minimized.

The sixth and last phase after QFD is guiding, which is done to achieve the goals in the customer need analyses. This phase is not handled in this thesis due to the reason that this phase is relevant when the designing has started.

5 METHODOLOGY

This part of the thesis is classified.

6 RESULTS

This part of the thesis is classified.

7 CONCLUSIONS

This part of the thesis is classified.

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APPENDICES

This part of the thesis is classified.