THESIS FOR THE DEGREE OF LICENTIATE OF ENGINEERING

Perceived Quality in the Automotive Industry

Defining Perceived Quality in the Automotive Industry, A Comprehensive Framework

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"Σα βγεις στον πηγαιμό για την Ιθάκη,
να εύχεσαι νάναι μακρύς ο δρόμος,
γεμάτος περιπέτειες, γεμάτος γνώσεις.

Τους Λαιστρυγόνας και τους Κύκλωπας,
τον άγριο Ποσειδώνα δεν θα συναντήσεις,
αν δεν τους κουβανείς μες στην ψυχή σου,
αν η ψυχή σου δεν τους στήνει εμπρός σου."

- *«Ιθάκη» Κ.Π. Καβάφης*

"As you set out for Ithaka
hope the voyage is a long one,
full of adventure, full of discovery.

Laistrygonians and Cyclops,
wild Poseidon—you won't encounter them
unless you bring them along inside your soul,
unless your soul sets them up in front of you."

- *«Ithaka» C.P. Cavafy*
(Translated by Edmund Keeley / Philip Sherrard)

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Abstract

The supremacy of the automotive manufacturers in the modern world is no longer driven by them achieving a superior manufacturing quality but increasingly depends on the customer's quality perception. The premium sector of the automotive industry is facing tough international competition. Studies within the automotive industry have identified that the perceived quality has become an important purchase decision factor. In practice, this means that the car manufacturers need to develop products that not only meet their customer's expectations but also exceed them. It is necessary to close the gap between engineering and customer perceptions of the final product.

Under such conditions, design process tasks are difficult in implementation because the evaluation of the perceived quality attributes is often subjective and intuitive rather than objective. The automotive industry demands methods and tools that allow the definition and validation of perceived quality related requirements.

Developing methods for objective assessment of the perceived quality attributes is a task with a very high level of complexity. The vehicle itself is a very complex product. This fact leads to the information asymmetry because the actual quality of the product is not always visible to the customer.

This thesis is a step towards closing the information asymmetry gap and bringing subjectively assessed perceived quality attributes to the objective side, supported by structured quantification methods. The author reviewed and structured product quality paradigms from the past, defined perceived quality attributes, described their properties regarding the premium automotive sector. The proposed comprehensive perceived quality framework is the major result of the thesis.

Keywords: product development, perceived quality, automotive, product quality, knowledge management.

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Gothenburg, September 2015
Konstantinos Stylidis

Appended Publications

The following research papers form the foundation on which this thesis stands.

Paper A

Stylidis, K., Hoffenson, S., Wickman, C., Söderman, M., Söderberg, R. (2014) *"Corporate and Customer Understanding of Core Values Regarding Perceived Quality: Case Studies on Volvo Car Group and Volvo Group Truck Technology"* The 24th CIRP Design Conference: Mass Customization and Personalization, 14-16 April 2014, Milan, Italy, Procedia CIRP, Volume 21, 2014, Pages 171-176

Paper B

Stylidis, K., Wickman, C., Söderberg, R. (2015) *"Perceived Quality and the Core Values in the Automotive Industry: A Corporate View"* DS79: Proceedings of The Third International Conference on Design Creativity, Indian Institute of Science, Bangalore p. 166-173. (2015)

Paper C

Stylidis, K., Wickman, C., Söderberg, R. (2015) "*Defining perceived quality in the automotive industry: an engineering approach*." The 25th CIRP Design Conference, 2-4 March 2015, Haifa, Israel (2015)

Paper D

Stylidis, K., Landahl, J., Wickman, C., Johannesson, H., Söderberg, R. (2015) "*Structuring Perceived Quality Attributes for Use in the Design Process*." International Conference on Engineering Design 2015 (ICED 2015), 27-30 July, Milan, Italy (2015)

Paper E

Stylidis, K., Hoffenson, S., Wickman, C., Söderman, M., Söderberg, R. (2015) "*Transforming corporate core values into perceived quality: An automotive case study.*", submitted to Journal of Industrial and Marketing Management, July 2015.

Paper F

Stylidis, K., Wickman, C., Söderberg, R. (2015) "*Perceived Quality in the Automotive Industry: Present, Past and Future.*", submitted to Research in Engineering Design Journal, August 2015.

Distribution of work

Paper A

Stylidis and Hoffenson wrote the paper, performed the data collection and analysis. All authors contributed in creating the case scenario. Wickman, Söderman and Söderberg contributed as reviewers.

Paper B

Stylidis wrote the paper and performed qualitative analysis of data using NVivo software. Wickman and Söderberg contributed as reviewers.

Paper C

Stylidis wrote the paper and did the literature review and analysis with the support of Wickman. Söderberg contributed as reviewer.

Paper D

Stylidis and Landahl wrote the paper, performed data collection and analysis. Wickman contributed to the empirical data. Johannesson and Söderberg contributed as reviewers.

Paper E

Stylidis and Hoffenson wrote the paper, performed the data collection and analysis. All authors contributed in creating the case scenario. Wickman, Söderman and Söderberg contributed as reviewers.

Paper F

Stylidis wrote the paper and did the literature review and analysis with the support of Wickman. Söderberg contributed as reviewer.

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1 Introduction

"There is no truth. There is only perception." –

Gustave Flaubert

The world we live in is changing and changing fast. Product development is evolving as are the expectations of the customers regarding products too. We are witnessing the major changes in the automotive industry caused by globalization and increased customer expectation on vehicle quality, safety and overall impression. The premium segment of the automotive business is facing tough international competition. The superiority of the automotive companies in this segment is no longer driven by delivering supreme technical quality, rather by the customer quality perception (Robinson, 2000), (R. Schmitt, Quattelbaum, & Falk, 2010), (Petiot, Salvo, Hossoy, & Papalambros, 2009).

In other words, the customer has to make a choice among technically excellent vehicles. Vastly changing trends can create countless quality misunderstandings. This fact brings automakers in the premium segment to the point where they have to obtain a holistic understanding of the meaning quality for the customer.

However, there is an information gap between customer perception of the vehicle quality and functionality, and the perceived quality attributes included in the product by the engineers. It is difficult to communicate some technical aspects, make an assessment of the perceived quality attributes and predict customer's opinion. Product development processes, especially at the early stages of design, that address perceived quality are prompted by a number of requirements that a product must fulfill. Additionally, in the premium sector of the automotive industry some of the requirements are driven by the internal competitiveness among the players. In this case, evaluation of the perceived quality attributes is a highly challenging process mainly because of the subjective nature of some attributes and intuitive approach of the designer (Eckert, Bertoluci, & Yannou, 2014). Often designers and engineers involved in the evaluation of the perceived quality attributes rely on their previous experience and intuition. This occurs mainly due to the lack of time, tight deadlines within product development timeline and other factors, even though the decisions they make are critical for the product success on the market (Ranscombe, Ben Hicks, Mullineux, & Singh, 2012).

Understanding the customer's perception of the quality is understanding the dimensions of perceived quality. There are numerous authors that have focused on the customer perception from different research perspectives. From one angle research is focused on the identification of the influences on the customer during product evaluation. From another angle, it measures and assesses the importance of the perceived quality attributes that have an impact on the customer preferences. Those preferences arise from the product attributes (aesthetic, functional, emotional) that signal quality to the customer (R. Schmitt et al., 2010). Consequently, two major problems have arisen: a) lack of the common terminology that would explain and define all forms of the perceived quality; b) deficiency of the methods and tools for objective evaluation of the perceived quality attributes.

There is a need to create a common vocabulary in terms of perceived quality related to the automotive industry. There is a need to support designers and engineers with the robust and reproducible methods that will allow to quantifying the customer's quality perception. The above mentioned factors substantiate a demand for a comprehensive perceived quality framework.

1.1 Defining perceived quality

Historically, perceived quality was part of larger quality models. Garvin, (1984a) proposed five quality approaches: transcendent, product-based, user-based, manufacturing-based and value-based. Perceived quality was defined by Garvin as a one of the dimensions of the product-based quality. Perceived quality together with the aesthetics were identified as the most subjective dimensions of quality. Such a classification limited measurability of perceived quality dramatically. However, it perfectly suits the "technocratic" way of product quality assessment as "conformance to the requirements" that prevailed at this time. Further development of the product quality concept followed with the separation of "objective quality" and exclusion of the subjective attributes such as aesthetics and brand image (Mitra & Golder, 2006). This approach derives from the attempts of marketing research to investigate the nature of the perceived quality. Zeithaml, (1988) described perceived quality as the subjective judgment regarding overall product quality made by the customer. Zeithaml proposed to see perceived quality differently from "objective" quality. Aaker, (2009) defined perceived quality as "customer perception of the overall quality.." continuing user-oriented tradition of the marketing research. Aaker

however, differentiates between perceived quality and objective quality, product-based and manufacturing quality.

In contrast, (Lieb, Quattelbaum, & Schmitt, 2008) came up with the view on perceived quality as "a scalable input factor for company's product development". This view is antagonistic to the idea that perceived quality is opposed to the objective quality and that perceived quality cannot be measured. Another example is Kansei Engineering methods that translate customer requirements into the product parameters (Nagamachi, 2002), supporting the idea of quantification of the perceived quality attributes.

Looking back to the traditional views on perceived quality two major concepts can be observed: marketing-oriented and engineering. The marketing approach focuses on the customer perspective, and the engineering approach is "zero-defects" quality.

As was mentioned previously the current state of the premium automotive industry demands a different approach to perceived quality exceeding "zero-defects" quality and proving robust methods for quantification of customer quality perception.

1.2 Research Focus

The overall purpose of this research is to create a structure of the perceived quality related subjects. Additionally, special consideration is given to the structuring and developing of robust methods for objective assessment of the perceived quality attributes. Better understanding of the perceived quality nature, supported by the perceived quality attributes evaluation methods, will help companies to develop products that meet customer requirements and allow manufacturers to be time and cost effective.

The research presented in this thesis elaborates on the concept of the perceived quality in product development – in particular providing a holistic view on perceived quality, based on the human sensory perception and multidisciplinary research.

There is vast theoretical and practical body of knowledge regarding product quality aspects including research in terms of perceived quality. This thesis addresses questions related to the perceived quality in the premium sector of the automotive industry.

The following points summarize the aim of the research presented in this thesis:

- Support for a paradigm shift of perceived quality in the premium automotive sector based on the proposed comprehensive perceived quality framework.
- Definition of the perceived quality attributes and establishing the foundation to objectively evaluate them.

1.2.1 Scientific Goals

From the scientific point of view the concept of the perceived quality has been a research topic for quite some time. However, previous research was quite polarized focusing either on the marketing angle, or on the engineering-oriented research with no relation to the customer. Brand strategists and psychophysicists have been focusing on some topics overlapping with perceived quality issues. Research into perceived quality up to this time is therefore fragmented.

Henceforth, the purpose of this research is to provide clear definitions of the perceived quality attributes, the creation of a joint language interconnecting science and industry. The comprehensive framework of perceived quality tailored for the automotive industry is a scientific contribution to the development and implementation methods regarding quality evaluation and assessment.

The ultimate goal of this thesis is to present a perceived quality framework connecting technology, product development, and industry.

1.2.2 Industrial Goals

The research project has been carried out in the close collaboration with the automotive industry. One of the major goals is a creation and structuring of the knowledge regarding perceived quality attributes and their properties. This will allow industry to see perceived quality in a broader perspective.

Another goal is the evaluation and assessment methodology for the perceived quality attributes. Ability to measure the importance of a particular perceived quality attribute as a part of the bigger and extremely complex system will give a great advantage to automotive manufacturers.

Further in terms of particular tools, evaluation techniques and methods for assessment of the customer quality impression, the goal is to support industry with a “tool-box” that exceeds the methods and instruments that are in use today.

At last, concept evaluation of the proposed framework is one of the primary industrial goals.

1.2.3 Research Questions

In this research, a number of research questions were identified. The main research question that addressed is:

RQ1. How can Perceived Quality requirements can be defined and validated on a complete vehicle?

To understand the cause of the particular problem, the following research questions arose:

RQ2. How can Perceived Quality feedback from potential and competitor's customers be gathered?

RQ3. What are the other techniques/functions and attributes that can affect and correlate to Perceived Quality?

1.3 Delimitations

Despite this project including different topics related to the product development and product quality, the basis of this research stands upon the grounds that are intended for the automotive industry. In particular, the scope of the analysis is the premium sector of the automotive industry. However, it is the author's desire that the findings from this research will be adopted by a broad number of the automakers including different market segments. Though, the same or similar set of attributes can be used with different relative importance. Furthermore, the perceived quality framework could be adapted to other areas of the product development than automotive.

This thesis focuses on the definitions and structuring a broad range of the perceived quality attributes including communication strategies. Thus, it will not provide particular methods for scaling and measuring the perceived quality attributes importance.

As this is licentiate thesis, the research will continue further to doctorate thesis, along with the validation of the proposed perceived quality framework. Consequently, the verification of the results in the real environment of the automotive company remains.

2 Frame of Reference

This chapter presents a brief overview of the research field, to familiarize the reader with the existing quality models, approaches and methods. Likewise, this chapter explains concepts, phenomena and the context to which the research in this thesis relates.

"Things are as they are because they were as they were"–

Thomas Gold.

2.1 What is Quality?

The definition of "quality" has a long history, and we are lucky to have the ability to trace its origin over the centuries. The word "quality" derives from the Latin translation of the Ancient Greek word "ποιότης" or "what-is ness". Cicero discovered it in one of the Socratic dialogues. Before Cicero's invention of "qualitas" European languages had no reference to the "what-is ness". Today it is hard to imagine science without a word like "quality" (Baars & Gage, 2010).

Particular interest in the definition and deployment of quality principles in the product development and production processes transpired after the Second World War, when Japanese industry experienced great difficulties regarding the quality and their attempts to overcome these issues.

Today quality has become an essential characteristic for the success of the Original Equipment Manufacturer (OEM) in the highly competitive global market.

2.1.1 The quality definitions as we know them

It is recognized by many authors that quality has a multidimensional structure. The well-known definition of quality as "fitness for use" is credited to Josef Juran. According to Juran, "fitness" is defined by the customer. Another view is held by Crosby, (1980) defining quality as "conformance to requirements". According to Crosby, requirements may not always fulfil customer's expectations. Robert Pirsig introduced "Metaphysics of Quality" as a theory of reality and breaks it into the two forms: dynamic quality and static quality patterns. According to Pirsig, (1999)

"Dynamic Quality cannot be defined. It can only be understood intellectually through the use of analogy."

Hence, there have been many independent approaches to defining quality, probably one of the most complete and powerful was conducted by the Japanese engineer Genichi Taguchi (Taguchi, 1986). Taguchi defines quality as "the losses of society caused by the product after its delivery" and as "uniformity around the target value". Though quality loss represents rather non-quality, in practice Taguchi's definitions apply not only to the products but the quality of services (Bergman & Klefsjö, 2010). Product development, according to Taguchi, consists of; Product quality (what consumers desire) and Engineering quality (what consumers do not want). In the first case, consumers desire functionality or appearance of the product and in the second consumers dislike high running cost, pollution or functional variability (Taguchi et al., 2005).

Furthermore (Kano, Seraku, Takahashi, & Tsuji, 1984) presented a model with two dimensions of quality: "must be quality" and "attractive quality". Kano used his definition in the model of customer satisfaction as the result of the company's performance.

Garvin, (1984b) introduced five approaches to the quality definition: *transcendent*, *product-based*, *user-based*, *manufacturing-based* and *value-based*.

A *transcendent* view is a philosophical approach which defines quality as "essential excellence". The roots of this approach lie in the Plato's discussion on the beauty and "platonic forms" where these forms cannot be defined. The same logic applies to the *transcendent* approach – it is hard to define what is excellent.

The *product-based* approach sees quality as an explicit and measurable variable. It is possible to measure *product-based* quality, according to the number of desired attributes that the product itself holds. This type of quality can be assessed objectively.

The *user-based* approach relies on the assumption that "beauty is in the eye of the beholder". It is based on the personal view of quality and is highly subjective. The "fitness for purpose" definition of quality perfectly fits into the *user-based* approach, where the user defines appropriate "fitness". The general agreement of views indicates that users often desire certain product attributes. However, this approach does not count the importance of the different product attributes in the overall customer impression.

The *manufacturing-based* approach, as opposed to the user-based, is primarily focused on engineering and manufacturing issues. Practically this approach sees quality as "conformance to the requirements", the view presented by Crosby, (1980). Once the requirements are set any deviations in terms of the specifications fulfillment or time deadlines are seen as a quality loss. According to the *manufacturing-based* approach, reducing the number of deviations leads to cost minimization and, as the results improve, quality.

The *value-based* views on quality act in terms of cost and price. According to the value-based approach to quality, the product provides the best ratio in terms of performance and cost or price. It is difficult to implement this approach in practice because there are no well-defined limits to measure the ratio of quality and value. Garvin claims that the result of this approach is the hybrid concept – "affordable excellence". A summary of the quality definitions is illustrated in the Table 1.

Table 1. Quality definitions by the various authors.

Author	***Quality Definition or Approach***
Juran	"fitness for use"
Crosby	"conformance to requirements"
Pirsig	"dynamic quality and static quality patterns"
Taguchi	"the losses of society caused by the product after its delivery" and "uniformity around the target value"
Kano	"must be quality" and "attractive quality"
Garvin	"transcendent, product-based, user-based, manufacturing-based and value-based"

It is also noticed by Garvin, (1984b) that views on quality are differentiated from the point of "marketing people" and "manufacturing people". The first type usually prefers user-based or product based approach, because they see a customer as a referee of quality. Accordingly, "manufacturing people" see quality as "conformance to the requirements".

Garvin identified the clear existence of this conflict in these two views. Such a conflict can seriously affect communication strategies in product development. In order to avoid conflicts, it is suggested that companies must be fully aware of these different quality perspectives. The assumption that a single definition of quality is sufficient may cause a potential problem. As the solution, Garvin proposes to shift

quality approach as a product moves from the early design stage to the production stage.

The characteristics that represent quality first have to be identified applying the user-based approach and translated into the product attributes using product-based approach. Afterwards to fulfill the requirements set by the number of product attributes, the manufacturing-based approach is applied.

Finally, there are eight dimensions of the product quality identified as a framework for quality.

- Performance (primary product characteristics, combination of user-based and product-based approaches)
- Features (secondary attributes that improve product performance and overall quality, include objective and measurable attributes)
- Reliability (frequency of failure, uptime)
- Conformance (match with the specifications, manufacturing-based related approach)
- Durability (closely linked with the Reliability, product lifetime)
- Serviceability (speed of repair)
- Aesthetics ("fits and finishes", related to the user-based approach, subjective)
- Perceived Quality (reputation and intangibles, related to the user-based approach, subjective)

In summary (see also Figure 1), Garvin recognizes the multidimensional nature of quality, highlighted critical points of possible conflict regarding understanding quality dimensions from the so-called "marketing" and "manufacturing" point of view.

To sum up, the quality definitions mentioned above formed the base for the ISO 9000 Quality System and its derivatives. The methods of implementation regarding quality are described in the next chapter, however the ISO 9000 defines quality as "fitness for purpose, conformance to the requirements, a product designed and made to do the job properly" (Rothery & Palacios, 1997).

2.1.2 Systems of Quality Engineering and Strategies

Eventually, there have been many independent approaches to the implementation of quality in the product development. Many of these approaches derive from the definitions of quality presented in the previous chapter. This thesis is focuses on the most recognizable and vastly implemented systems in the practice of the design and production.

Figure 1 – Product Quality Framework, as proposed by Garvin, (1984b)

The development of quality methodology over the last decades clearly indicates a shift from activities of inspection towards process control, preferably at the early stages of product development. It is well known that the relative cost of a design changes increases dramatically over the time of the production process. A change in the early stages of the product development is less expensive than a change in the later stages or even if a product has already been produced (see Figure 2). It is a primary reason for why quality control is so important to implement in the early phase of design and production. Additionally, the fact that production timelines are getting shorter and shorter is another reason that quality controls should be

implemented as early as possible. Often there is simply no time to test a product on the market, resulting in a necessity of highest quality standards from the launch.

It is also necessary to mention, that the modern view on quality focuses on the customer. The customer is the one who evaluates the final product. To be able to satisfy customer's demands and be competitive, companies implement different quality strategies.

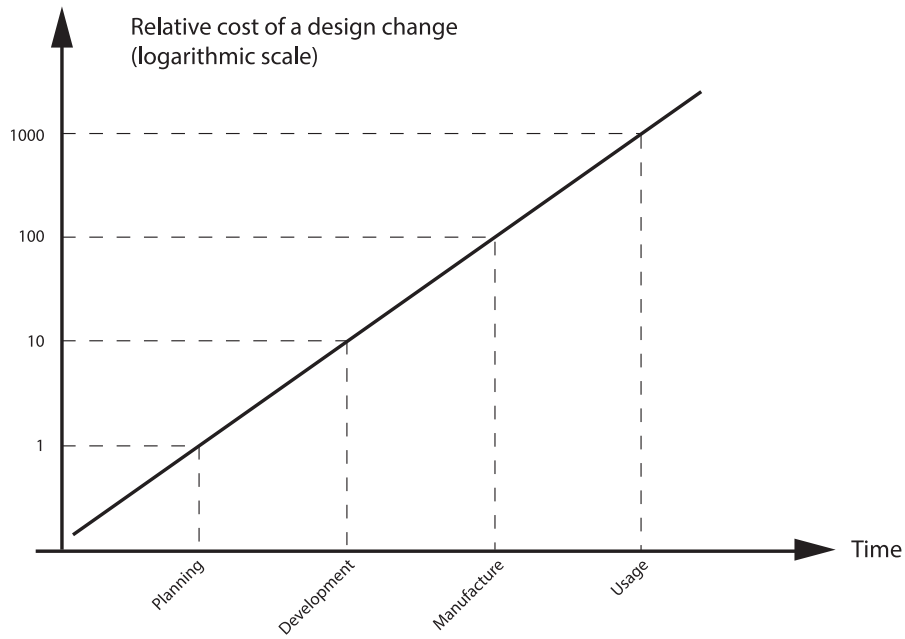

Figure 2 – The cost of design change a function of time. Adopted from (Bergman & Klefsjö, 2010)

2.1.3 Taguchi's System of Quality Engineering.

The important methodology that attracted considerable interest in the industry is Taguchi's philosophy. The central idea of his quality engineering system is the use of the product as a base. As is mentioned in the previous chapter, Taguchi's view on product quality (or rather an absence of quality) is the quality loss and financial loss after the product is delivered to the customer.

According to Taguchi et al., (2005) "quality loss is caused by deviations from ideal performance" and it is a loss to "society" including manufacturers and

customers (see Figure 3). Taguchi clearly differentiates product characteristics from quality characteristics. The number and choice of product characteristics depend on the certain market segment. Quality characteristics however, are a set of deviations from the ideal product quality in the same market segment (Bergman & Klefsjö, 2010). It is impossible to eliminate all deviations and disturbances, and Taguchi proposes that design has to be robust. Robust design is insensitive to the disturbances that can affect a product.

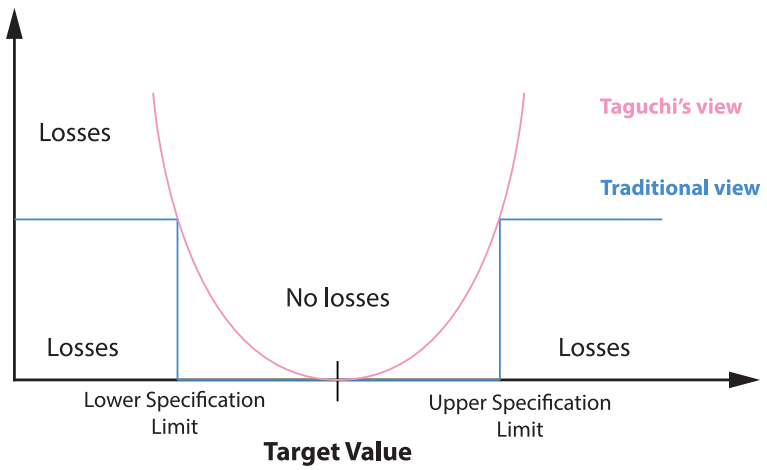

Figure 3 – Traditional approach so called "Step function" and Taguchi's Quality loss function. Adopted from (Taguchi et al., 2005)

The system of quality engineering using robust design has four activities according to Taguchi. The most significant improvement activity is the *product parameter design* that keeps performance close to the ideal value of customer satisfaction. Other activities include *tolerance design*, *process parameter design* and *online quality control*. This paradigm represents total quality development (Clausing, 1994).

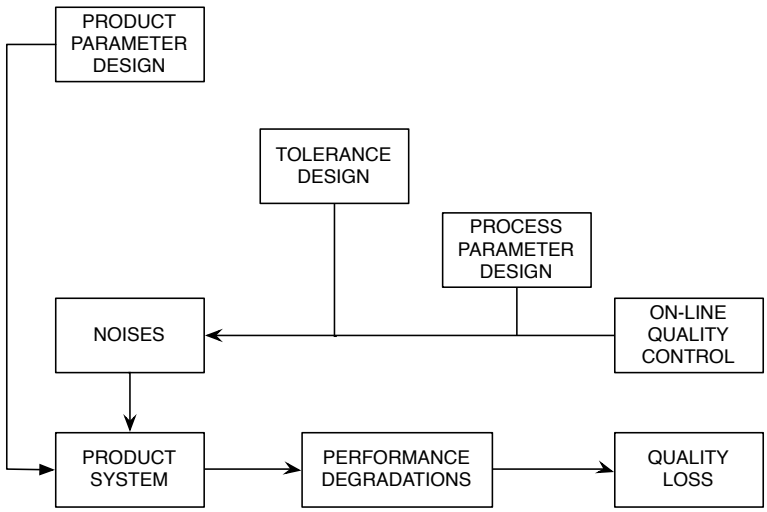

Figure 4 – Taguchi's system of quality engineering.

The essential elements of Taguchi's system of quality engineering are illustrated in Figure 4.

2.1.4 Quality Function Deployment and House of Quality

The boost in global competitiveness over the last decades required an enormous number of decisions to be made. The primary approach to handle such decision making is *Quality Function Deployment* (QFD) introduced by Hauser & Clausing, (1988) and a further development of it: *Enhanced Quality Function Deployment* (EQFD) presented by Clausing & Pugh, (1991). The EQFD usually utilizes team experience in terms of decision making and if experience alone is not enough the use of Taguchi's methods is suggested. This approach is shown in Figure 5.

To summarize, this approach forms the total quality development and puts emphasis on quality loss prevention rather than a reaction to the problem at the later stages of product development. It is also a strongly customer oriented approach, and it uses team experience in decision making (Clausing, 1994).

An essential part of the EQFD visualization is the matrix form known as *House of Quality*. *House of Quality* allows arrangement of activities from the voice of the customer to the shop floor.

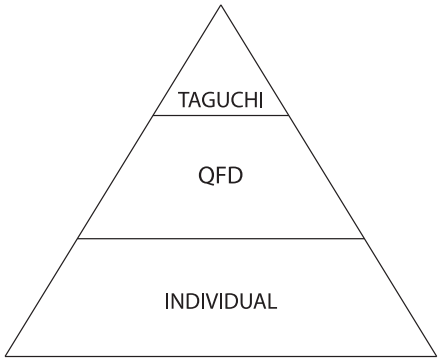

Figure 5 – Decision making process as a combination of EQFD and Taguchi's methods

The *House of Quality* is a very effective way of product planning compared to traditional activities mainly due to the elimination of rework that traditionally occurs in the late stages of the product development process. Overall, the *House of Quality* consists of eight "rooms" as shown in Figure 6. Room 1 is the voice of the customer, a series of activities to identify the customer need. The customer attributes are usually determined by qualitative research with the different types of interviews and/or focus groups (Griffin & Hauser, 1993). It is critically important to translate customer attributes into technical requirements, and this is done in Room 2. The technical requirements are measurable and specified in the House of Quality as "How's". To overcome the issues that may appear during the process of a voice of the customer translation to the technical attributes, the House of Quality includes a relationship matrix in Room 3. The benchmarking Rooms 4 and 5 are fulfill the purpose of planning not only a new product but even a product with a better quality. Room 4 is for benchmarking of customer's perceptions and Room 5 is the company's targets areas including objective measures that reflect a link between customer attributes and technical requirements. The product development team compares two sets of benchmarks for consistency until are results a coherent. Room 6 or "the roof matrix" is the correlation matrix where positive and negative correlations among technical requirements are indicated. Room 7 is where the project planning is done. The team usually estimates the difficulty in a change of the technical requirements, usefulness and cost of such changes. Room 8 is the final action plan including the quantification of the company's expectation regarding the new product (Clausing, 1994).

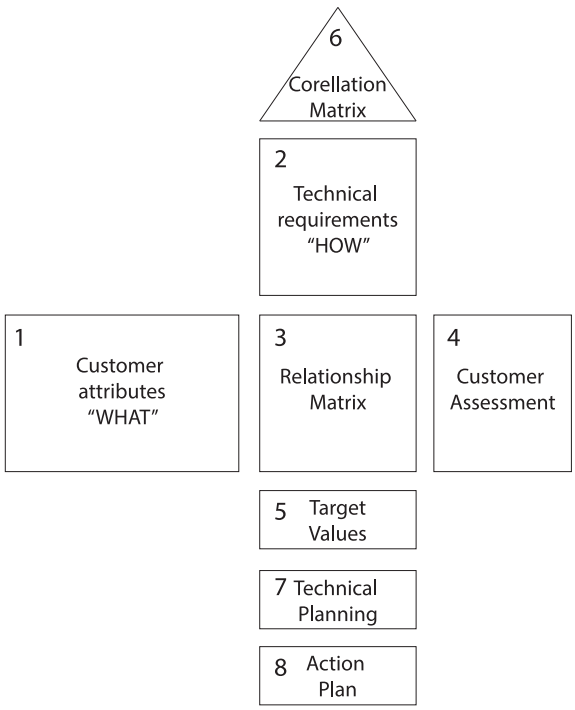

Figure 6 – House of Quality.

2.1.5 Kano Model of Customer Satisfaction

Professor Noriaki Kano has developed a very useful model for customer satisfaction. The quality dimensions in the Kano model are separated into three groups as perceived by the customers: must have needs, expected needs and delights or exciting experiences (see Figure 7).

The basic needs are the requirements represented by the bottom line and the customer simply expects them to be there. If those requirements are not fulfilled, the customer will be very dissatisfied.

The expected needs are such needs that the customer is aware of and expects those to be fulfilled.

The delights are not expected by the customer, however, the absence of the delights often leads to the customer's dissatisfaction. One way to surprise the

customer is to present technologically advanced attributes, another is the services (Kano et al., 1984).

Hence, customer requirements change over time. As an example, the seat comfort was an excitement in the automotive industry a few decades ago. Today, in the premium segment, the seat comfort is a necessary prerequisite.

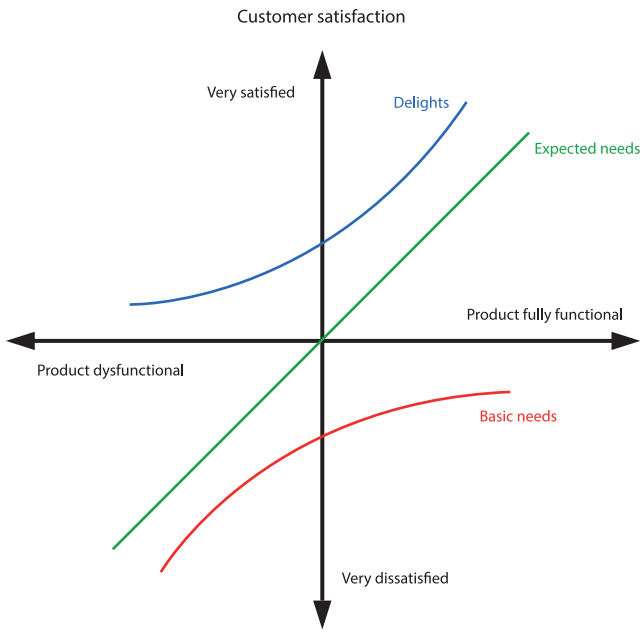

Figure 7 – The Kano model of customer satisfaction

Later, Kano added another three categories of customer's requirements: indifferent, reverse, questionable. Indifference means that customer do not care if the requirement is fulfilled or not. It has no influence on the satisfaction level. Reverse indicates customers' dislike of the requirement and questionable indicates contradictory customer's opinions.

The degree of the customer satisfaction on one hand influenced by the customer's expectations and awareness, and on the other hand brand loyalty and heritage, plays a significant role in the customer's satisfaction.

For the preparation of the Kano diagram, there is data collection is needed. Usually, thee data is obtained from the customers with the help of a questionnaire. The questionnaire is designed so that two questions are asked for each customer

need. The need is stated in a negative and positive way. The responses to both questions are analyzed, and customer requirement is classified as one of the six Kano categories. The Kano evaluation table is the key to the a interpretation of the anwers. (see Table 2).

Table 2. Kano interpretation.

		Negative statement				
Positive statement		1.Like	2.Must be	3.Neutral	4.Live with	5.Dislike
	1.Like	Q	D	D	D	E
	2.Must be	R	I	I	I	M
	3.Neutral	R	I	I	I	M
	4.Live with	R	I	I	I	M
	5.Dislike	R	R	R	R	Q
	D-delighter; M-must have; R- reverse; E- expected; Q- questionable; I-indifferent.					

2.1.6 QC-Circles and Kaizen Philosophy

An important factor of the quality improvement is the quality management within the organization. The quality policy deployment is an important element of the *Total Quality Management system*. Such a policy may contain various components and strategies. Historically one of the first organized approaches to involving employees in the quality improvement process was the activity usually referred as *QC-circles* (Quality Control Circles). The idea of the *QC-circles* was developed in Japan in the 1960s. *QC-circle* is usually a study group consisting of 6-10 members having the goal to study literature regarding quality control. The self-development of the employees is the primary objective of the *QC-circle*. As a result, group members can discuss, analyze and solve different problems regarding product quality and product development process. It is essential that *QC-circles* get support from the management teams in the quality activities and results. However, it is necessary to mention that the *QC-circles* approach had certain problems with the adaptation to Western companies (Blair & Whitehead, 1984).

"*Kaizen*" is a term derived from the Japanese and it means "change for the better." "*Kaizen*" is presented as one of the fundamental principles of the *Total Quality Development* process. The ultimate goal of the "*kaizen*" philosophy is the awareness of customer satisfaction to keep the business profitable. "*Kaizen*" is based

on the employee's commitment and participation in a continuous improvement of the workflow. Unfortunately, "*kaizen*"- based activities are often misinterpreted either as "an endless "free lunch" of improvements which emerge magically from the workers" or as "the mundane application of suggestion schemes and quality circles (QCs)" (Paul Brunet & New, 2003). Nevertheless, the "*kaizen*" philosophy can be described as a continuous path through the checkpoints: Plan-Do-Study-Act. The comprehensive description of the "*kaizen*" philosophy is also provided by (Masaaki, 1986).

2.1.7 The Six Sigma Quality Approach

Another methodology worth noting in the aspect of Total Quality Development is the Six Sigma. The history of Six Sigma is well documented and known as a quality improvement approach introduced in the 1980s by Motorola. The name "sigma" derives from a statistical measure related to the capability of the process to produce non-defective products. In statistics "sigma is a measure of process variation referred to as the standard deviation and "six sigma" generally implies occurrence of defects at a rate of 3.4 defects per million opportunities (DPMO) for defects to arise" (Klefsjö, Wiklund, & Edgeman, 2001). Therefore, in Six Sigma statistical techniques are used in a systematic way to reduce variation and improve quality control processes. Six Sigma, as with other approaches within the concept of Total Quality Development, is customer oriented and focused on the results. Snee, (2000) stated that "Six Sigma should be a strategic approach that works across all processes, products, company functions and industries".

2.1.8 The ISO 9000 Quality System

The previous chapters discussed methods and strategies for improvement of product quality. Many companies had a demand for documented quality system. Such a system was introduced by the International Organization for Standardization in 1987 and is known as the ISO 9000 family of standards. Since then ISO 9000 standards has been translated into the national standards of quality in more than 50 countries (Rothery & Palacios, 1997). As a standard, ISO 9000 consists of five parts (see Figure 8). Part 1 provides the guidelines for the use of the other standards in the group. Overall, the group of standards include requirements for quality assurance and guidelines for quality management (Hoyle, 2005). The ISO 9001 is the model for

quality assurance in design/development, production, installation and servicing. The ISO 9002 is the model for quality assurance in production and installation. The ISO 9003 is the model for quality assurance in final inspection and test. The ISO 9004 is the description of quality management and quality system elements in ISO 9000. The ISO 9000 is a guideline for selection and use of the standards.

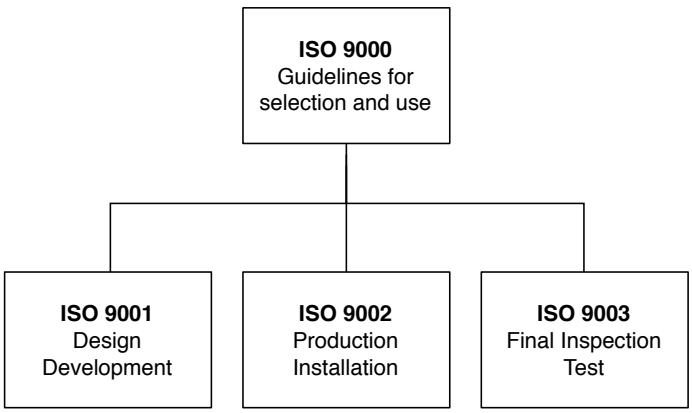

Figure 8 – The ISO 9000 Quality System

Thus, ISO 9000 group of standards is a combination of the concepts and principles that have been applied in organizations previously. Despite the important role of the ISO 9000 in the implementation of quality standards, there are some deficiencies – the system is defensive, and product oriented rather than progressive and process oriented. As Dr. Juran said: "There is nothing in ISO 9000 about continuous quality improvement, customer satisfaction or employee participation." (Bergman & Klefsjö, 2010). Additionally, there is no definition of perceived quality in the ISO 9000 family standards.

2.2 Elaborating the Idea of Perceived Quality

As it has been noted previously, Garvin (1984b) identified aesthetics and perceived quality as the most subjective dimensions of product quality. Aesthetics, according to Garvin, is a perception of a product by human senses. Such a perception is influenced by the appearance of a product, haptics, sound and smell characteristics.

Perceived quality, as it is stated by Garvin, derives from incomplete information about product attributes and incorporates intangibles such as brand image and reputation. According to Garvin, advertising has a similar impact on the customer impression as the aesthetics and perceived quality (Garvin, 1984a). Monroe & Krishnan, (1985) define perceived quality as "perceived ability of a product to provide satisfaction relative to the available alternatives." Steenkamp, (1990) proposed the definition of the perceived quality as "…value judgment with respect to the fitness for consumption which is based on conscious and/or unconscious processing of quality cues in relation to relevant quality attributes within the context of significant personal and situational variables". Mitra & Golder, (2006) interpret perceived quality as "perception of the customer" and oppose it to the term "objective" quality. "Objective" quality, according to Mitra and Golder, is the performance combined with all product attributes, and it can be measured by the use of mixed methods or expert ratings. "Objective" quality excludes subjectively assessed attributes like aesthetics and "external" attributes such as brand image. The definition of perceived quality presented by Mitra and Golder derives from the earlier research of Zeithaml. Zeithaml, (1988) defines perceived quality as the subjective customer's judgment regarding overall product superiority. Perceived quality is different from objective quality, according to Zeithaml.

Another "marketing" point of view of perceived quality is represented by David Aaker. Aaker, (2009) sees perceived quality as "the customer's perception of the overall quality or superiority of a product or service with respect to its intended purpose, relative to alternatives. Perceived quality is, first, a perception by customers. It thus differs from several related concepts, such as:

- Actual or objective quality: the extent to which the product or service delivers superior service.
- Product-based quality: the nature and quantity of ingredients, features, or services included.
- Manufacturing quality: conformance to specification, the "zero defect" goal."

Aaker & Jacobson, (1994) also established a link between perceived quality and financial performance.

Castleberry & McIntyre, (2011) discussed aspects of perceived quality as: ".. a belief about the degree of excellence of a goods or service that is derived by examining consciously and/or unconsciously, relevant cues that are appropriate and

available, and made within the context of prior experience, relative alternatives, evaluative criteria and/or expectations".

Moreover, Lieb et al., (2008) presented a retrospective review about the evolution of the perceived quality definitions and how they influence the purchase behavior. Lieb et al. proposed to see perceived quality as "a scalable input factor for a company's product development". The development of this approach is the research presented by R. Schmitt & Quattelbaum, (2010) where perceived quality is defined as "the result of a cognitive and emotional comparison process between customer's conscious and unconscious expectations regarding criteria like price, design, brand image or product experiences and the realized technical product features in specific situations of use". In contrast to the "traditional" view of perceived quality as a subjective factor, the approach mentioned above points towards objectification of the perceived quality attributes (I. R. Schmitt & Neumann, 2013). Lieb et al., (2008) developed a methodology that provides a structured approach to quantification of the customer's overall impression and transformation into the technical parameters. R. Schmitt et al., (2010) introduced a five stage framework for integrating perceived quality related information to the product development (see Figure 9). In contrast Eckert et al., (2014) stated that in such complex situations as car design the existing methods for quantification of the product attributes do not work correctly.

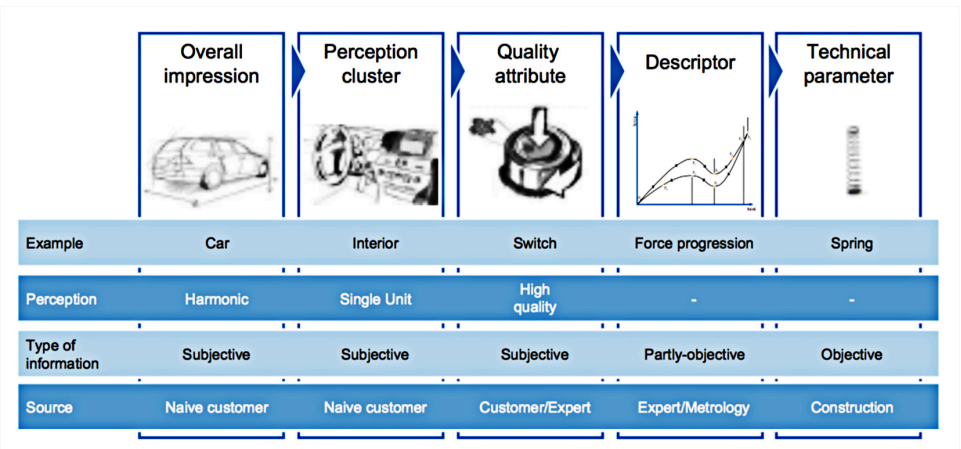

Figure 9 – The five-stages framework according to (R. Schmitt et al., n.d.)

Analyzing the views on perceived quality, two major views are portrayed: marketing-oriented approach and engineering approach. The marketing-oriented

approach focuses on the user-based quality view and the engineering approach looks towards objectifying and quantification of the perceived quality attributes. In the premium segment of the automotive industry, this approach is combined with the lack-of-defects quality that is the prerequisite in this market segment. Therefore, according to Garvin, (1984b) these views are in potential conflict in regards to the communications issues and also due to occurred information asymmetry. A summary of the views and the variety of approaches on perceived quality is illustrated in Figure 10.

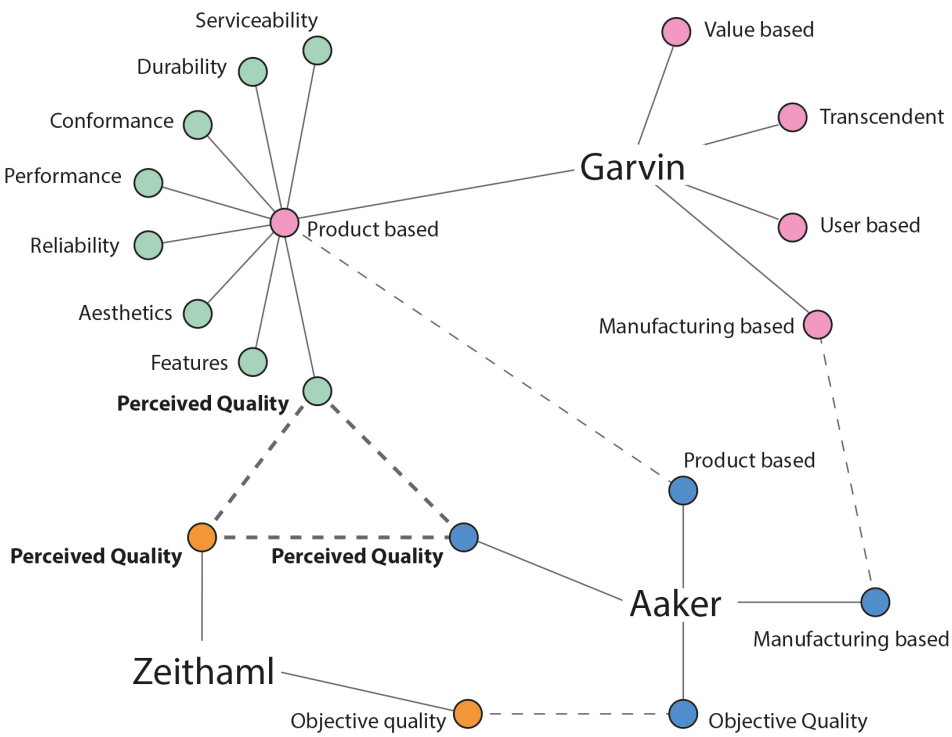

Figure 10 – The major views on perceived quality

2.3 Perceived Quality in the Automotive Industry

The research regarding the perceived quality elements applicable to the automotive industry is focused on a number of relevant areas such as: brand image and heritage, visual and aesthetic quality, different technical aspects related to the haptic perceptions, material quality, sound quality and craftsmanship. The research regarding brand, core values and craftsmanship is mainly marketing oriented in comparison to other areas which use the product-based or even manufacturing-based approach. After all, customers today demand not only zero defects quality but they also expect products to be error-free. This is highly applicable to the automotive industry. Likewise, the vehicles become more and more homogeneous with a high level of integration among basic functions. This fact is forcing industry to find new areas of differentiation (I. R. Schmitt & Neumann, 2013) and academia to perform research in such areas.

2.3.1 The Brand Image and Brand Heritage

In the past, a classic brand manager dealt with the simple brand structures, few brand extensions, and few sub-brands because of the simple environment and simple business strategies. Today the situation is quite different, and brand managers are facing market fragmentation, channel dynamics, and globalization. To be able to deal with these changes and complexities, brand managers have no other choice but have to create aggressive brand extensions, complex structures with a number of sub-brands (Aaker & Joachimsthaler, 2000). According to Aaker and Joachimsthaller sub-brands are playing the role of co-drivers that increase perceived quality of a brand. Stylidis, Hoffenson, Wickman, Söderman & Söderberg, (2014) confirmed this trend of the sub-brands use in the case study of Volvo Car Group and Volvo Trucks. Homer, (2008) describes the relationship between brand image and quality, bringing attention to cases with a conflict between product quality and its perceived image. Homer concludes that the brands with a low perceived image are in the worse position regarding the customer's judgment than brands suffering from the low actual product quality. Homer claims that "data suggests that strides in quality are not as powerful as efforts aimed to enhance brand image, at least for some product categories such as cars." It is a good illustration of the cause of information asymmetry where the customer often is not aware of all technical details of the product.

Lobschat, Zinnbauer, Pallas, & Joachimsthaler, (2013) in their study structured multifaceted formative construct, social currency, and investigated further how the social currency influences brand equity in the case of the automotive industry. They found that social currency has a positive influence on the perceived quality of the brand.

The brand heritage is a very important influencer on the vehicle purchase decision. An extensive methodology regarding consumers' perception of the heritage brands restricted to the automotive industry is presented by Wiedmann, Hennigs, Schmidt, & Wuestefeld, (2011). The evolution of the brands together with the future of brand management presented in the research of Wiedmann, (2015) acknowledges the complexity of the present and future challenges.

2.3.2 The Difference between Luxury and Premium.

A clear understanding of which factors form the foundation of the premium automotive brand and the difference to the luxury brand is essential. Although the terms "luxury" and "premium" are widely used in the communication strategies of the automotive manufacturers very often these terms are misinterpreted or bring confusion both to the manufacturer and to the customer. There is a lack of understanding about which components comprise luxury or premium: where should the money be spent, which perceived quality attributes make a difference (de Jongh Hepworth, 2007).

In general terms, premium is a prerequisite to luxury. However, there is no clear borderline or clear measurement scale to distinguish premium from luxury.

Hennigs, Wiedmann, Behrens, & Klarmann, (2013) define the concept of luxury as "highly subjective, situational contingent and depending on the experience and individual needs of the consumer."

Wiedmann, Hennigs, Klarmann, & Behrens, (2013) states that "..key characteristics of luxury brands include a perceived high price; excellent quality; exclusivity and uniqueness in the sense of scarcity or severe availability; aesthetics of form and colour; a long history and the reputation of a holistic and continuous brand presence; and non-necessity, as symbolic values which dominate over the functional characteristics."

The key difference between luxury and premium is the fact that premium is more about product quality. Luxury communicates a more personal approach while premium is all about a product that exceeds customer's expectations.

A good example of misinterpretation of the concept of quality in terms of luxury/premium is the case of Volkswagen Phaeton: "Volkswagen pulled its Phaeton from the U.S. market because American consumers were not willing to buy the 6-figure "best car in the world" if it had a VW nameplate." (Homer, 2008). Lesson learned - two years later Volkswagen successfully launched Bentley Continental GT on the platform of VW Phaeton.

2.3.3 Vehicle's Visual Quality and Aesthetics.

Numerous researchers investigated different aspects of the aesthetics and visual quality of the vehicles. Aesthetics and aesthetic judgment, in particular, is often seen as highly subjective elements of quality, comprising of intangible notions such as pleasure, beauty and taste. Quite often, in contrast, aesthetic judgment is referred to processes that have particular outcomes with certain triggering characteristics (Xenakis, Arnellos, Spyrou, & Darzentas, 2012). Visual quality is not limited to the appearance rather it is a complex phenomenon which includes interaction with the product. The quantification of the product attributes referred to as visual quality is the primary goal of the research majority.

Crilly, Moultrie, & Clarkson, (2004) presented a conceptual framework for consumer perception of the visual product form. Crilly et al. adopted Shannon's model of communication (Shannon, 1949) to the product design, concluding that "product form may provide for unarticulated consumer requirements and suggest product qualities that are otherwise difficult to ascertain"

Warell & Young, (2011) developed the *Perceptual Product Experience* (PPE) framework. The particular framework provides a structure to support design work in terms of validation of the perceptual product experiences. Ranscombe et al., (2012) observed the influence of different aesthetic attributes on the customer's brand perception. Proposed visual decomposition strategy of the vehicle image can improve vehicle appearance evaluation. Burnap, Hartley, Pan, Gonzalez, & Papalambros, (2015) investigated dependency of the changing vehicle visual attributes and brand recognition by the customer. This contributes to the knowledge about the extent of design freedom using quantitative models for aesthetic related attributes evaluation. Fu & Sun, (2013) explored the usage of material aesthetics in the car design. Reid, MacDonald, & Du, (2013) attempted to quantify subjectively perceived quality attributes regarding vehicle silhouette design.

Quite often a customer has no indicators to signal durability of the product, as a result the focus will be on the aesthetic impression of the product. For this reason, connection uniformity or consistency (e.g. of gap dimensions) are important (R. Schmitt & Quattelbaum, 2010). The design of the vehicle consists of some components that are in structural relation to each other (Dagman, Wickman, & Söderberg, 2004). A split line is defined as the relation between two parts over a specified distance. The split line may have some parameters and characteristics like gap, flush, level of parallelism or curvature. Gap and flush as a characteristic of a split line is a factor that influences perception of the aesthetics by the customer. Wickman & Söderberg, (2007), Stoll & Paetzold, (2008), presented results of gap and flush evaluation in terms of visual quality in a virtual environment.

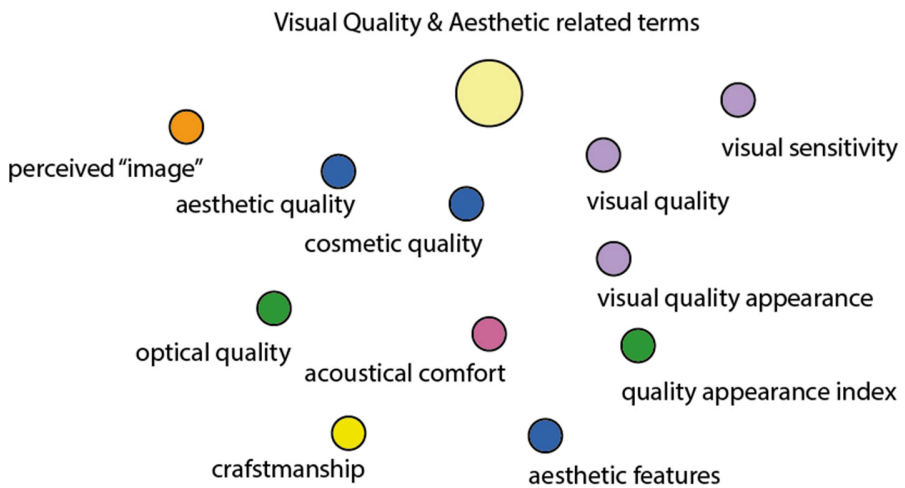

Figure 11 – Schematic illustration of the terms range related to visual aspects of perceived quality

Albeit, visible controversy regarding the definition of aesthetics and visual quality still exists. Maxfield, Dew, Zhao, Juster, & Fitchie, (2002) define aesthetic quality as: "*Aesthetic quality* has no precise definition, since it is a qualitative attribute that is perceived by a customer through visual inspection and comparison. It may be loosely defined as the 'look' of the product." Juster et al., (2001) discuss the term "cosmetic" quality and describe it as: "*Cosmetic quality* has no precise definition. It is a customer perceived product attribute. It may be loosely defined as

the ‘look’ of the product.” Such an approach complies with the “marketing” view on aesthetic as one of the quality dimensions, but also contributes to some confusion in terms of the exact definition of visual quality. Hazra, Roy, Williams, Aylmore, & Hollingdale, (2013) introduced an inspection method for evaluation of the *cosmetic quality* of automotive skin panels. Penzkofer, Wittmann, & Winter, (2008) presented visual analysis method for non-ideal assemblies since tolerance values have an impact on aesthetic requirements.

Forslund & Söderberg, (2007; 2008); Forslund, Dagman, & Söderberg, (2006) provided some noteworthy papers regarding visual sensitivity, effects of geometrical variation on perceived quality and *optical quality* as the product attribute. Dagman et al., (2004) introduced *Visual Quality Appearance* (*VQA*) in the empirical case study investigating the relationship of the *VQA* and the split lines of the vehicle. Wickman & Söderberg, (2001) defined *Quality Appearance Index* as a part of a visual quality evaluation. Wagersten, Forslund, Wickman, & Söderberg, (2011) developed a framework supporting evaluation of split lines perceived quality at the early stage of product development.

To sum up, despite the quite extensive research in the area of visual perceived quality evaluation there are certain gaps and overlaps in the definitions (see Figure 11).

2.3.4 Craftsmanship.

Craftsmanship is often referred to as the perception of quality experienced by a customer. Craftsmanship is associated with four critical elements, which are the customer’s perception of quality, the ability to stir emotions, sensory interaction and skillful manufacture or workmanship (Turley, Williams, & Tennant, 2007). Craftsmanship requires attention to the details in such areas of product development as: appearance – in terms of exterior/interior execution; solid function - functional operational fitness; superior fit and finish, choice of material – authenticity. Consequently, craftsmanship combines not only a quality of design but even quality of the design execution.

Wang & Holden, (2000) developed a craftsmanship evaluation method that calculates an overall craftsmanship score for the vehicle. The score is a sum of individual product attribute assessed subjectively. With a similar approach Ersal, Papalambros, Gonzalez, & Aitken, (2011) developed a procedure for analysis of vehicle interior characteristics and perceived attributes of craftsmanship. Previously,

Turley et al., (2007) discussed a final vehicle product audit methodology, which includes craftsmanship evaluation. Petiot et al., (2009) illustrated the customer's craftsmanship perception of the vehicle interior with a cross-cultural case study. An effort to develop a comprehensive methodology regarding quality perception measurement of interior material was presented by Bhise, Hammoudeh, Nagarajan, Dowd, & Hayes, (2005).

In essence, the concept of craftsmanship is very similar to the notion of the perceived quality. It includes involvement of many skills, serves to express quality and can be measured objectively. The author believes that the craftsmanship can be seen as a synonym for Technical Perceived Quality in reference to the premium sector of the automotive industry. However craftsmanship do not include attributes that belong to Value-based Perceived Quality.

2.3.5 Sound Quality, Noise, Vibration and Harshness (NVH).

The research in terms of sound quality with application to the automotive industry is quite focused and industry driven. There are particular problems, certain methods and solutions concerning the elimination of NVH, or the definition of the proper sound feedback within the solid function validation. Generally speaking, in the premium segment of the automotive industry, sound quality is the essential part of the overall customer perception and sound feedback is part of the communication like a particular "clock sound" of the closing door in the Mercedes vehicles. Equally important is the elimination of unwanted sounds in terms of NVH. This area of analysis is linked to the other variables e.g. tolerances, since the modelling of the situations causing unwanted sounds is essential in the early stages of product development. The engineering team has to predict and model a behavior of different parts of the vehicle under various conditions like temperature difference, road condition and other types of stress.

Kim et al., (2010) developed and applied a process of the vehicle cockpit optimal design that minimizes permanent deformation. The noise that plastic interior parts can produce is one of the major contributors to the perceived quality of a vehicle.

Sontacchi et al., (2012) developed a methodology for predicting noise caused by the powertrains in the vehicle's interior.

Weber et al., (2013) developed the E-LINE method that allows squeak and rattle simulations to be integrated as a standard CAE delivery in the design process. Rattle

may appear when the dynamic movement between two components of the vehicle exterior/interior is larger than the defined nominal gap (see Figure 12).

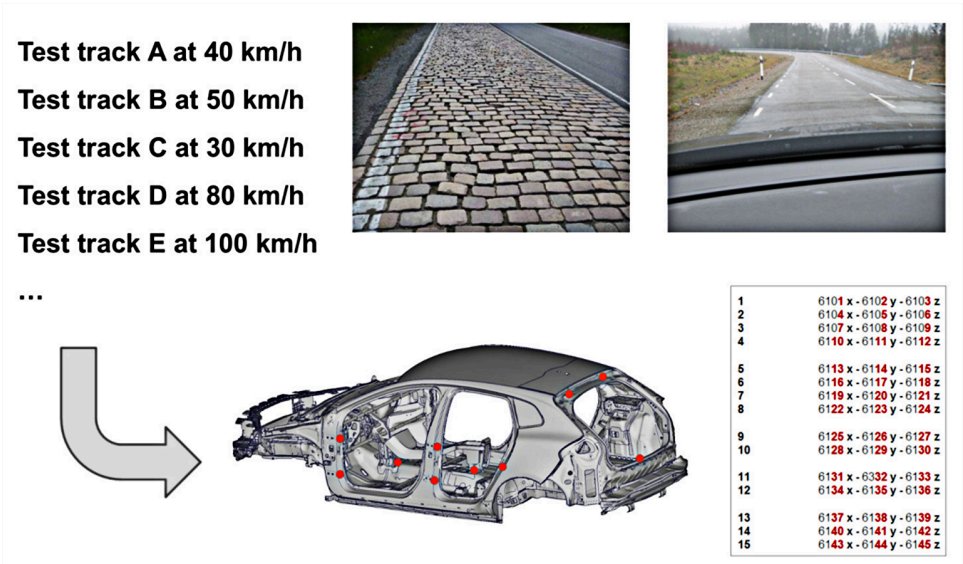

Figure 12 – Squeak&Rattle test and data recording (Weber, Sabiniarz, Wickman, Lindqvist, & Söderberg, 2013).

Sköld, (2008) have presented analysis of perception and customer's reaction to the sounds in vehicles. Jung, (2012) described factors influencing acoustic comfort in the vehicle. Genell, (2008) analyzed sound perception in heavy trucks.

2.3.6 Methods for Assessment of Perceived Quality Attributes.

The need for robust assessment techniques and evaluation methods of the perceived quality attributes is evident and has been discussed in the previous chapters. Despite the continuous pursuit and far-reaching progress in terms of quantification and objectification of the intangible perceived quality attributes, the overall picture remains heterogeneous.

One of the most popular methods for gathering customer requirements and translation of those into the technical specifications is the Kano method (Kano et al., 1984). However, the Kano model does not include customer's sensorial perception. Some of the customer's requirements have a subjective or unconscious character and cannot be captured by this method (Tsiotsou, 2006).

The Kansei Affective Engineering (Nagamachi, 2002) is the method of translation the emotional feelings and image perceptions of people into physical design parameters. Kansei methods support the understanding of subjective perceived quality attributes, but the process of translating these into physical properties is time-consuming and the customer's view expression is limited to the spoken words (so-called "kansei words") (Eckert et al., 2014; Schütte, Eklund, Axelsson, & Nagamachi, 2004)

A variety of statistical techniques for marketing research are highly applicable to the studies of perceived quality: conjoint analysis (W. Y. Wu, Liao, & Chatwuthikrai, 2014); combination of the semantic differential method with the Maximum-Difference Scaling (MaxDiff) (Louviere, 1993). However, it is difficult to incorporate into the difference modelling the subjective perceptual attributes e.g. regarding visual quality (Ren, Burnap, & Papalambros, 2013).

The qualitative methods such as structured, semi-structured interviews, and focus groups are widely in use. Therefore, the rich data acquired by these methods is often evaluated subjectively.

A relatively new, but very promising method of gathering customer's perception, is eye-tracking. Eye-tracking is method for capturing eye gaze and fixations while a person is observing visual stimuli. These methods allow the capture of direct feelings and responses of the consumer to be analyzed later with a scientific and quantitative method (Chang, Chiung-Pei, & Min-Yuan, 2013). A combination of eye-tracking with the qualitative research methods is very promising technique in terms of capturing customers requirements and their translation to the technical specifications.

The question of time that needs to be allocated to the definition of the consumer's requirements is critical. With the continuously shortening of the production lifecycle, the demand for robust methods of the perceived quality evaluation will only increase. The integration of the customer's requirements into the product development process have to be structured, systematic and supported with robust methodology (Falk & Schmitt, 2014).

2.4 Conclusions of the frame of reference

The scope of the research presented in this thesis aims to address the issues above. The perceived quality attributes have to be defined allowing designers and engineers to "speak the same language" at every stage of the product development. Although perceived quality is a relatively common topic of the scientific publications rather limited research has been performed with the engineering approach. The definition of the perceived quality attributes is fuzzy and, in some cases, mutually exclusive.

Dissemination of the perceived quality attributes to manageable areas is essential regarding quantification of the previously subjective assessed areas. Still the big and open question for the research community and industry is: on which perceived quality attributes engineers have to focus to achieve the highest level of the customer's appreciation.

3 Research Approach

A body of knowledge that is the foundation for a discipline is produced through research. To obtain scientifically transparent and credible research results different disciplines use a variety of approaches. The research presented in this thesis is conducted within discipline of design science. This chapter describes the reasons why the particular approach was chosen, and how it was adopted to fit the boundaries of this research.

3.1 Design Research and Science

Many definitions of design exist; Engineering Design is usually referred to as a set of activities that results in developing a product or knowledge. The particular product or knowledge has to fulfill a customer's need and needs of other stakeholders. The design as a process includes activities such as requirements specification, concept phase and detailed design, process planning and manufacturing systems design and optimization system analysis.

Blessing & Chakrabarti, (2009) describe design as "..not only a knowledge-intensive activity, but also a purposeful, social and cognitive activity undertaken in a dynamic context. Design is a complex, multifaceted phenomenon, involving: people, a developing product, a process involving a multitude of activities and procedures; a wide variety of knowledge, tools and methods; an organization; as well as micro-economic and macro-economic context."

According to Hubka & Eder, (1987) design science is " … the problem of determining and categorizing all regular phenomena of the systems to be designed, and of the design process. Design science is also concerned with deriving from the applied knowledge of the natural sciences appropriate information in a form suitable for the designer's use".

Design research evolution consisted of three phases: Experimental, Intellectual and Empirical (Wallace & Blessing, 2000). The Experimental phase, which existed until the late 1950s, included activities of the senior designers. They wrote about their experiences in the design process and the results. These observations were not placed within any framework and were specific to the domain they described. The Intellectual phase that followed lasted about 20 years. During this stage, the emphasis

was placed on the creation of a design basis using a variety of methodologies and principles of a design process. The Empirical phase started in the 1980s with the empirical studies. It's purpose was to understand how the designers perform a process of design. The Empirical phase investigated what impact new methods and tools had on this processes (Blessing & Chakrabarti, 2009).

3.2 Available Theoretical Frameworks.

There are several different methods and frameworks that provide theoretical basis for researchers. In particular, the theoretical framework of the design includes the following research methodologies: TRIZ (Altshuller, Shulyak, & Rodman, 1999), Domain Theory by (Andreasen, 1991), Mathematical Theory of Design by (Braha & Maimon, 2013), Function-Behavior-Structure framework (Gero & Kannengiesser, 2004), CK-Theory (Hatchuel & Weil, 2003), Theory of Technical Systems by (Hubka & Eder, 1987), Axiomatic design (Suh, 2001) and others.

3.3 Design Research Methodology.

The methodology of this research project is based on the Design Research Methodology (DRM), a framework developed by (Blessing & Chakrabarti, 2009). The DRM focuses not only on aiding the process of providing understanding of design, but provides a rigorous path to more effective and efficient design research. The DRM consists of four main phases (see Figure 13) and it is iterative methodology which means the phases implementation is not necessarily executed in the chronological order. Additionally, it may not be possible to perform all stages of the framework within the boundaries of one research project (Blessing & Chakrabarti, 2009).

Phase 1 is the research clarification (RC) and the main goal is to define a success criterion that will evaluate success of the research. The main method and source of information regarding this stage is the Literature study. In the next phase so-called Descriptive Study I (DSI), the researcher usually tries to clarify the situation and detect possible problems and research gaps, if any. At this point an extensive literature review is performed together with the empirical studies if needed. Normally DSI act as a basis for the third phase – Prescriptive Study (PS). The PS addresses those problems, depicting how to affect them to improve the existing situation with

development of a new methods and tools. The next phase, Descriptive Study II (DSII) aims at evaluating the true effects of the support implemented.

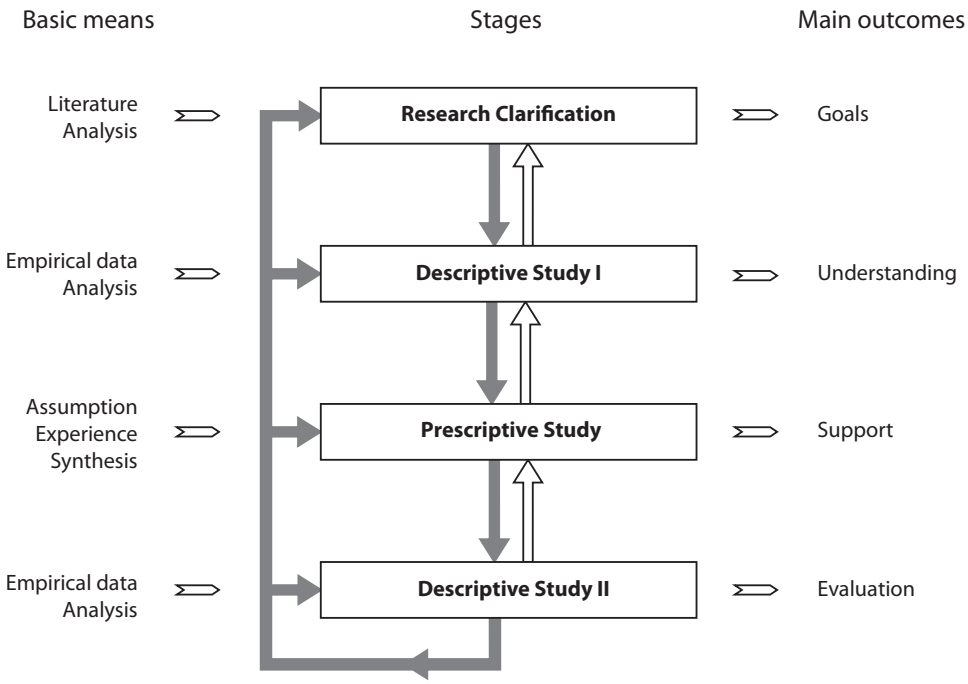

Figure 13 – DRM Framework by (Blessing & Chakrabarti, 2009)

To sum up, each phase stage contains a pool of activities and deliverables to aid the researcher.

To determine the focus of the research, it is necessary to identify the success criteria in relation to the main research question. Success criteria according to Blessing and Chakrabarti (2009) relate "to the ultimate goal to which the research project intends to contribute and usually reveal the purpose of the research". The aim of research presented in this thesis is a creation of generic framework for perceived quality. Such a framework can establish a foundation for developing robust methodologies regarding objective assessment of perceived quality attributes. The ultimate goal of this research is to develop a tool for objective evaluation of perceived quality in the automotive industry. The research approach is represented by the mix of methods such a combination of qualitative and quantitative research methodologies. Development of the perceived quality framework is immediately

related to the major research question: “How can Perceived Quality requirements can be defined and validated on complete vehicle?”

3.4 Methodology Applied in this Thesis.

This chapter describes how the research methodology has been applied in this thesis. As foundation of this process the following aspects will be considered: research questions, DRM phases, published papers and types of result, methods used and studies performed.

3.4.1 Research Questions and the DRM Phases.

The ultimate goal of this research project is to generate new knowledge and evaluation tools and methods regarding perceived quality in the automotive industry. To achieve this, a number of research questions were generated. RQ1 deals with the complete understanding of perceived quality nature and definition of the majority of perceived quality attributes. In the papers C and F, a comprehensive framework for perceived quality, supported by a rich Literature review, is presented. RQ2 is important mainly because in practice the industry has a certain need of the robust methods for collections and analysis of the customer’s requirements. The production time in the automotive industry has a tendency to decrease and this fact necessitates the search for effective user-centered methodology. Papers A and D present methods and tools that partially answer RQ2. In the Paper A, a procedure of semi-structured interviews as a part of the qualitative study is presented. The results of the interviews are the list of the perceived quality attributes, which were evaluated by the customers with the use of survey and semantic-differential scale together with the Maximum Difference Scaling method. RQ3 deals with the external factors that form the perceived quality. Papers B and E, with the use of qualitative analysis, provide insights into the evolution of the perceived quality attributes, and their allocation in the particular automotive companies. All three research questions are in the Descriptive Study I stage.

The allocation of the research questions in the DRM framework is within the Descriptive Study I stage and has a particular reasoning. The reason for such an extensive empirical research is the nature of perceived quality. Many of the perceived quality elements have a fuzzy construct, little previous research exists, visible controversy and redundancy in the terminology and definitions was detected

too. All factors mentioned above stress the focus on the need for clear understanding and verification of the perceived quality framework, before the proceeding to the stage of Prescriptive Study (see Figure 14).

3.4.2 Type of Results.

There are several types of results that form the basis of the current research presented in this thesis.

- Descriptive results: in the papers: Papers A and D provide empirical data leading to a better understanding of the design process.
- Descriptive methods and tools: Papers B and E present methods for collecting data and further analysis.
- Phenomenology of perceived quality: Papers C, F and partially Paper D investigate a phenomenon of perceive quality.
- A framework of descriptive study: in the Papers C and F a framework of perceived quality is presented.

3.4.3 Methods Used.

There are numerous approaches for collecting data within design research such as samplings, interviews, group interviews and observations. Methodologies can be combined like case study and action research. Case study is the one of commonly used approaches within research design. Yin, (2013) defines a case study as a process of "investigation a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident."

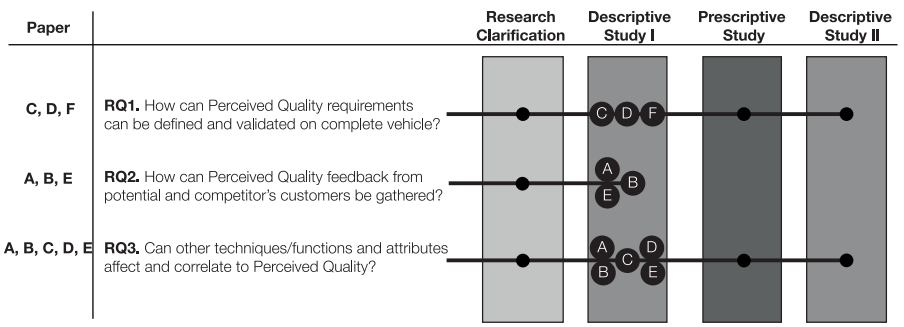

Figure 14 – Distribution of the paper A-F in the context of DRM Framework

The interview is one of the most widely used methods in qualitative research (Yin, 2013). Interview studies are typically classified as structured, unstructured and semi-structured interviews. Papers A, B, D and E include qualitative evaluation of the selected industry professionals with the use of semi-structured interviews. The semi-structured interview normally includes elements from both structured and unstructured interviews. Cachia & Millward, (2011) describe semi-structured interviews as follows: "A fixed set of sequential questions is used as an interview guide but additional questions can be introduced to facilitate further exploration of issues brought up by the interviewee, thus almost taking a form of a managed conversation". Additionally, in Papers B and E the transcribed interviews were coded and analyzed with the use of NVivo – a qualitative data analysis computer software package (Welsh, 2002).

To capture the customer's perception of perceived quality attributes, a Paper A and E include the quantitative survey. One of the methods used in the survey is Maximum Difference Scaling (MaxDiff), which is the quantitative choice-based technique used for understanding a respondent's or respondent group's relative valuation of different products or product attributes. MaxDiff is used along with the questions using the more common semantic-differential scaling, which is the one way to avoid lack of discrimination and confounding among respondents (Magidson, Thomas, & Vermunt, 2009).

To understand the existing body of knowledge the Literature study was performed in Papers C, D and F. The Literature study is the essential prerequisite in order to map the proposed methods and definitions, as well as to determine any existing gap in the knowledge related to perceived quality.

3.4.4 Validating the results in applied research

Validity has a different meaning for different people in the different research fields and context. Cook, Campbell, & Day, (1979) identified four major threads to validity: construct, internal, external and statistical. Nanda, Rivas, Trochim, & Deshler, (2000) stated the need of an interdisciplinary approach to address complex problems in the research. Perceived quality in the automotive industry is an outstanding example of the highly complex and diverse research topic.

The results presented in this thesis were shared and analyzed with a broad range of experts to achieve the external acceptance. More explicitly, all papers have been

undergoing peer reviews as part of the publication process. Paper A, B, C and D have been presented at conferences as a podium presentation where experts within the field and other disciplines had opportunities to express their opinions about the results. Additionally, as a part of the external verification process, the preliminary findings have been presented to the industrial partners of the Wingquist Laboratory. Papers E and F were submitted to the peer-reviewed high ranked scientific journals. The body of Literature as the basis for this research is accounted in Chapter 2.

A large base of state-of-the-art research regarding quality evolution over the time within product development is presented. Known quality models and approaches are reviewed. The research created a new phenomena model for the perceived quality.

4 Results - Summary of the Appended Papers

This chapter presents the results from the papers that are appended to this thesis. Some of the papers provide answers to the research questions while some contribute with the relevant information and elements of the research. The summary presented in this chapter focuses mainly on the results, hence not all the papers will be described equally regarding the details. The full descriptions can be found in appended papers.

4.1 Paper A

Purpose.

The paper presents a study performed in cooperation with the leading Swedish vehicle manufacturers: Volvo Car Group and Volvo Trucks. Both of these companies share the same three core values: Quality, Safety and Environmental Care. However, they approach these values in different ways due to different customer demands. The purposes of this study are to investigate how designers convey core values to customers through product attributes and how customers perceive those core values through the same attributes.

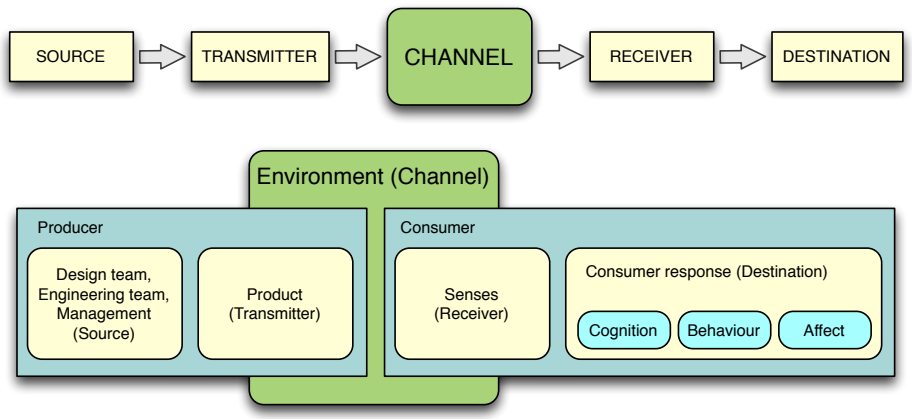

Figure 15 – Basic framework for design as the process of communication adapted from (Crilly et al., 2004)

Methods.

As a background for this study a Shannon's communication model was adapted for the process of communication in design (see Figure 15).

The study was designed as a combination of in-depth, semi-structured interviews with professionals, complimented with the surveys performed on drivers. The interviews brought valuable information regarding communication strategies and the ways of setting requirements to fulfill core value-related needs. The gathered information provided the source for formulation of the lists of product attributes that correspond with each of the core values of both companies. These lists were used in the subsequent survey of car and truck drivers.

The main results.

The semi-structured interviews with professionals revealed several interesting trends. Both companies are perceived as premium brands. This fact presents the conclusion that in the premium segment a technical quality is no longer a differentiator. In relation to the core values, safety is a highly perceived Volvo brand heritage. Professionals also believe that safety is highly perceived by the customers, and the quantitative survey confirms that.

The quantitative survey of drivers confirmed some of the trends pointed out by professionals while also providing important insights into how the consumers value different attributes and assess vehicle quality, safety, and environmental care.

4.2 Paper B

Purpose.

The research that provides the backbone for paper B is an in-depth qualitative analysis of the data gathered during the case study described in paper A. The particular study explores how professionals from the Volvo Car Group and Volvo Trucks understand their company's core values and transfer these into perceived quality attributes. The purpose of this study is to investigate emerging industry trends and make steps towards elicitation, objectification and distribution of the perceived quality-related features.

Methods.

The paper describes the complex nature of perceived quality and the challenges regarding assessment of the perceived quality attributes. In particular appearance is one of the product features that is quite often assessed subjectively and is directly

linked to visual aesthetics. Muller, (2001) analyzed different flows of aesthetic appreciation theory such as: numerical aesthetics, minimalist aesthetics, psychological aesthetics and semantic aesthetics. These flows provide different points of view regarding aesthetics and the presented study revealed, among other things, the trend of simplification of complex technical systems while presenting them to the customer. Implementation of such a strategy could actually lead to underestimation and misjudging of the final product by the customer. Berlyne's theory, presented in the 1960s, states that an optimum grade of complexity exists and it is perceived as most appreciated by the customer Any extreme complexity values are less attractive (see Figure 16).

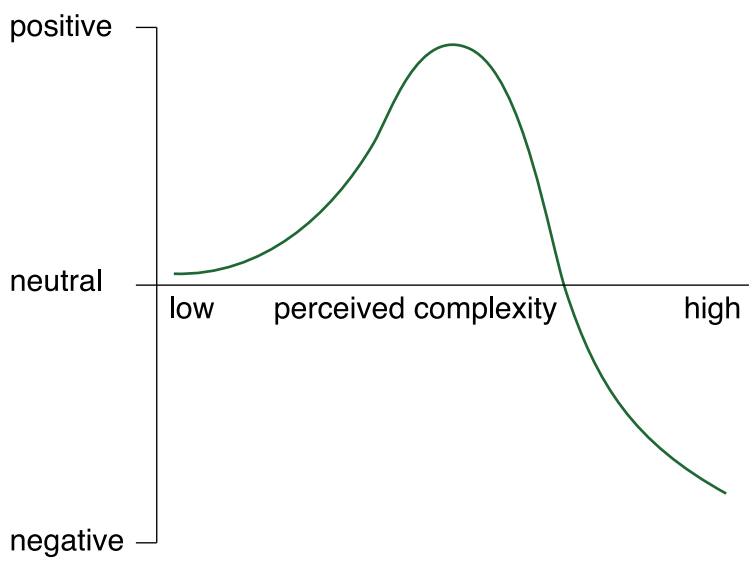

Figure 16 – The relationship between perceived complexity and the degree of attractiveness according to Berlyne (Muller, 2001). Adapted from (Warell, 2001)

A qualitative study with the use of semi-structured interviews with automotive industry professionals was performed. Interviews revealed a list of perceived quality attributes that represent core values and the trend analysis was later carried out based on received data.

The interview analysis was carried out with the coding technique and use of the qualitative analysis software – NVivo. The proper use of the coding techniques together with the manual analysis can add rigor to the analysis process by "allowing

the researcher to carry out quick and accurate searches of a particular type can add to the validity of the results by ensuring that all instances of a particular usage are found" (Welsh, 2002).

The main results.

In this paper for the first time a preliminary concept of the perceived quality framework has been introduced. The idea that perceived quality in the automotive industry has a dualistic nature is presented together with the definitions of Technical Perceived Quality and Value-based Perceived Quality. It is stated that design processes regarding perceived quality attributes are driven by the set of requirements that has to be fulfilled on the complete vehicle. Evaluation of these properties is very often subjective, intuitive rather than objective. There is a high demand for the methods and tools that can define and validate perceived quality related requirements for the complete vehicle.

As the outcome of the study, the analysis of data delivered by the interviews explained divergences between Volvo Car Group and Volvo Trucks branding and communication strategies. Among them was: professionals believe that the exterior design is one of the major buying factors; one of the emerging factors for perceived quality is HMI (human-machine interface); movement towards intuitive interfaces; customization of the vehicles for different markets; shift towards clustering and creation of sub-brands

Both companies operate as premium brands, and the data shows that they are seeking new ways to communicate their core values. The study highlighted that the methods of communication with customers regarding technical details of the vehicle and its characteristics have dramatically changed. Interviews revealed a significant shift from technocratic ways of presentation into more emotional approaches that fulfil the customer's needs.

4.3 Paper C

Purpose.

The paper present analysis of existing research in the automotive industry in terms of definition and evaluation of perceived quality attributes.

The results in this paper are derived from the state-of-the-art literature review on the evolution of the quality definitions and in particular perceived quality. Furthermore, this paper presents a perceived quality framework based on the primary

human senses, and distribution of the perceived quality attributes within this framework.

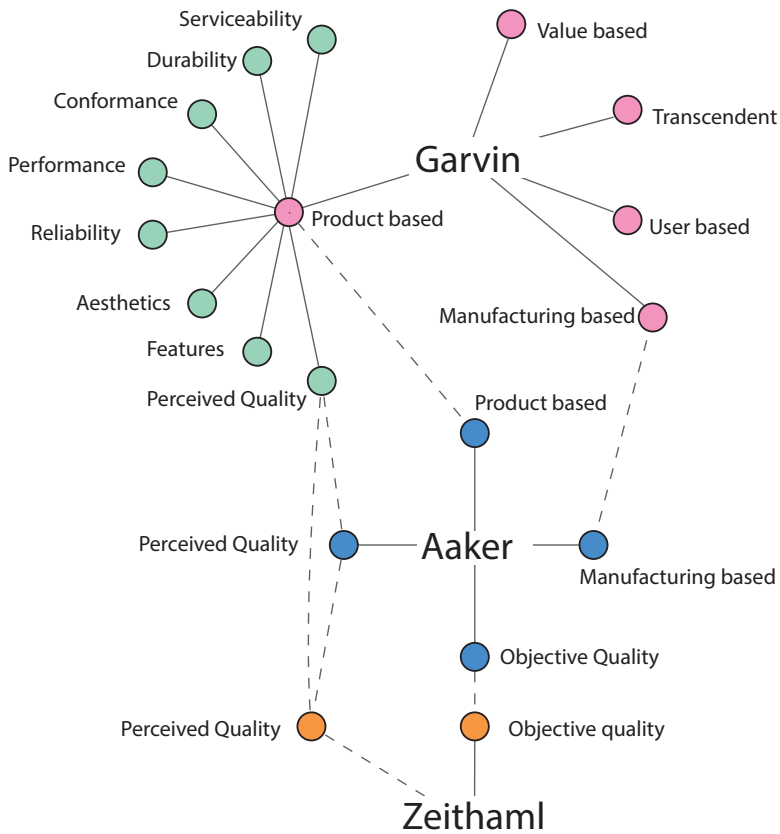

Figure 17 – Schematic illustration of the quality dimensions, approaches and the links within, derived from the Literature.

Methods.

The primary methodology used in this study is a Literature review. The literature analysis shows that there is a number of the main views on the perceived quality – marketing and engineering oriented. Nevertheless, perceived quality remains on the subjective side and often opposed to the "objective" measurable technical quality (see Figure 17)

The marketing point of view focuses on the user-oriented approach while engineering focuses on the lack-of-defects quality. The consequences are the potential conflict in the communication between engineers and customers, which is shown in the paper E.

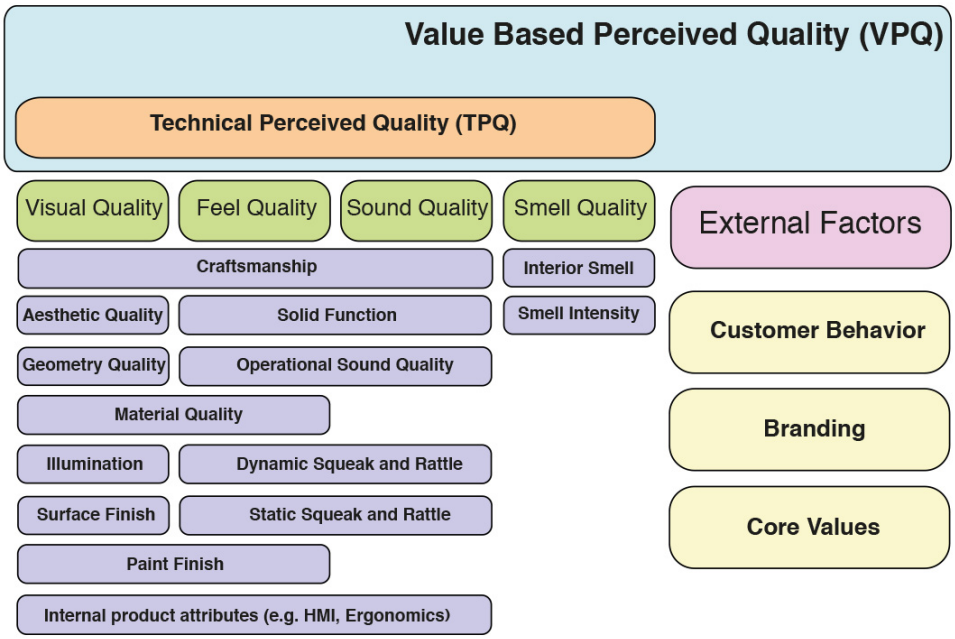

Figure 18 – Illustration of the conceptual terminology framework of perceived quality in the automotive industry.

The main results.

One of the outcomes of the study is that despite that perceived quality related aspects have drawn much attention over the past decades, there are certain gaps and overlaps in terms of the definition of perceived quality.

This study presents a comprehensive terminology framework of perceived quality based on the primary human senses. It provides also a new definition of perceived quality. "Perceived quality itself in the automotive industry has a dualistic nature. The authors propose a definition as *Value Based Perceived Quality* (VPQ) and *Technical Perceived Quality* (TPQ). The VPQ embody the total customer experience of the product attributes and external factors (e.g. brand heritage) through

the senses and cognition. The TPQ represents the engineering approach, based on the level of individual technical aspects of the product, perceived with the purpose to fulfill customer requirements and competitiveness. TPQ is the subset of VPQ" (Stylidis, Wickman, & Söderberg, 2015).

The study provides some interesting insights: competitiveness is one of the critical dimensions regarding perceived quality. In the premium segment of the automotive industry the number of players is limited and consecutive, setting up of the customer requirements is highly influenced by the competitors.

The Figure 18 illustrates the perceived quality framework presented in the paper.

The main elucidation that can be drawn from this paper is the conclusion that in the automotive industry application of the user-based approach to quality, through marketing research and identification of product related requirements that represent quality is hardly manageable on the stage of translation of these requirements into the product attributes. In the first place because of the subjective origin of some product attributes and lack of information regarding the importance of such attributes to the customer. For this reason, the correct definition of the perceived quality attributes is essential, especially for highly complex processes like vehicle manufacturing. Dissemination of the perceived quality attributes to manageable areas is important regarding the objective evaluation and quantification of the areas previously subjectively assessed.

4.4 Paper D

Purpose.

This paper proposes an integrated approach of incorporating a new terminology framework of perceived quality into the product design process. A case study was conducted at the automotive company to depict the current state of information management. A platform system model was presented for better integration of the perceived quality attributes into a design process.

The agile automotive manufacturer will not only recognize the need to assess attributes objectively but also the need to store attributes neatly to support reuse for various design applications better. To integrate information regarding perceived quality attributes in information management systems for future reuse is fundamental to eliminate rework and frequent manual interventions. However, storing information of perceived quality for reuse in design has many limitations. Therefore, decisions

that the design engineer has to make will be based on individual experience and intuition (Ranscombe et al., 2012). These decisions may affect the product, and how the customer perceives the quality of the product. Thus, the perceived quality attributes need to be carefully assessed and utilized in the design. Due to the competitive nature of the automotive industry, there is a lack of time, lack of money and overflow of rework, thus little room for making proper inclusion of perceived quality attributes.

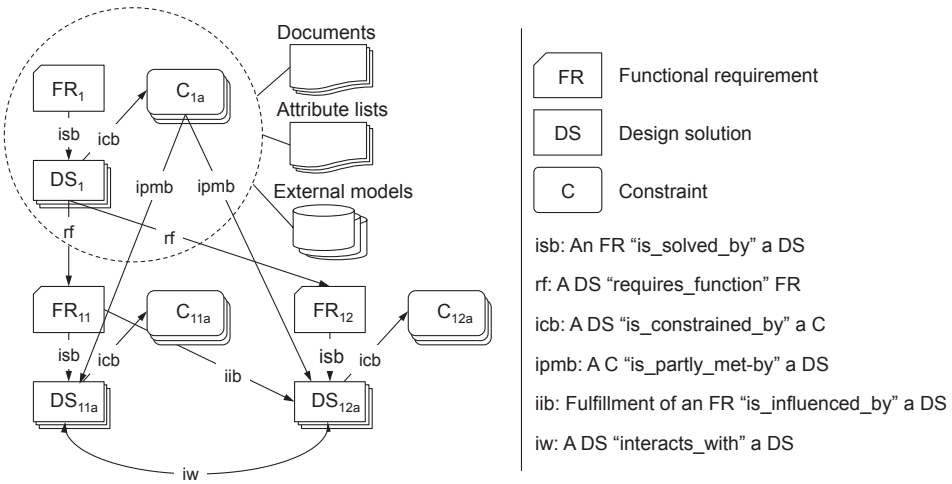

Figure 19 – Illustration of elements adhering to the platform system model Configurable Components (CC) concept.

Methods.

As a method paper utilizes the information received from the ten semi-structured interviews conducted with the senior-level engineers and managers working cross functionally between departments, dealing with the information integration. The interviews were voice recorded and transcribed into text. The study proposes to use the Configurable Component (CC) concept and the Enhanced Function-Means modeling for incorporating the knowledge regarding perceived quality attributes into the PLM systems. The CC concept is an object-oriented approach to describe system platforms. It contains reusable elements. Reusable platform elements can be used to structure information about a product. Each CC element holds a system family, containing information about the system solution itself, the means to compose system variants and its underlying requirements and motivations, i.e. its Design Rationale

(DR). The Design Rationale is based on Enhanced Function-Means (E-FM) modeling. E-FM modeling describes the interactions between Functional Requirements (FRs), Design Solutions (DSs) and Constraints (Cs). An illustration of a CC object and the theory behind EF-M modeling is shown in Figure 19.

Furthermore, in this paper the Perceived Quality Framework, introduced in the papers B and C was further enhanced with the exclusion of the term "craftsmanship" from the top level of the framework. After numerous discussions with the industry professionals, it is clear that in the premium segment of the automotive industry craftsmanship is a synonym for Technical Perceived Quality.

From reviewing the literature and examining historical events in the auto industry, it is interesting to note that perceived quality has evolved, both in academia and in industry. The concept of perceived quality has expanded to something that needs to be further incorporated into the design process in more detail compared to early initiatives.

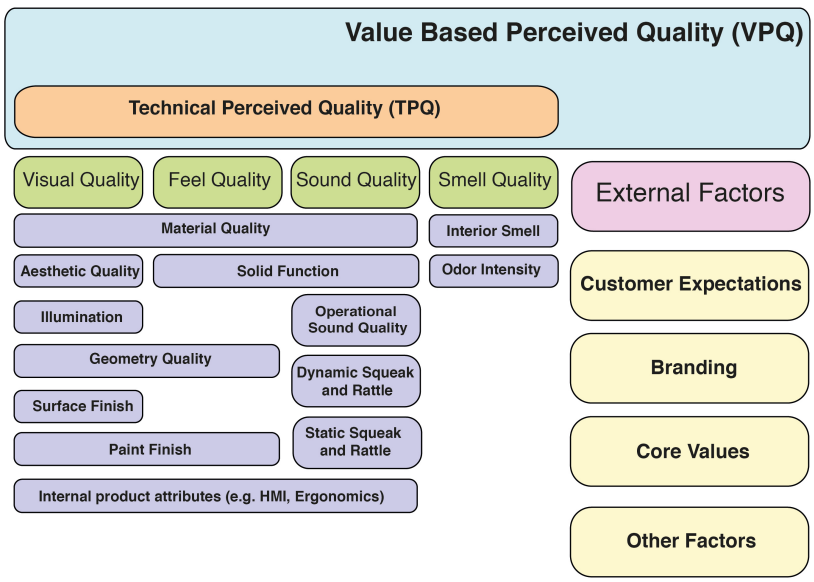

Figure 20 – The evolved terminology framework of the perceived quality in the automotive industry.

The main results.

Back to the case study, it was found that the company has one distinct group working with perceived quality. However, there are four additional groups working

with technical perceived quality, according to the presented terminology framework illustrated in Figure 20.

The five groups are, as for now, scattered throughout the organization. Thus, even though there are unifying similarities between the groups, such as recurring interactions between various applications in the design process, the groups are partitioned into different departments. Each department has its way of managing documents with restrictions to certain users. However, all departments use the same centralized PLM systems. It is apparent that the information is scattered and that there is a need to better integrate information between the departments and the systems that they use (see Figure 21).

Overall, the paper presents:

- a terminology framework for perceived quality, applicable for the automotive industry.
- a broad literature review has shown that the definitions of perceived quality and its elements are rather fuzzy, especially for automotive application.
- an initial study at an automotive company concluded that incorporating perceived quality attributes in the existing PLM systems is cumbersome.

To further structure and integrate these attributes ready for use in the design process, the concept of platform-based development and reusable platform elements is a possible way forward.

Future work will be employed to further investigate the limitations of incorporating perceived quality in the design process, model an illustrative case of perceived quality attributes using Enhanced Function-Means (EF-M) modeling to verify and to promote the ability to reuse PQ Attributes in the design process.

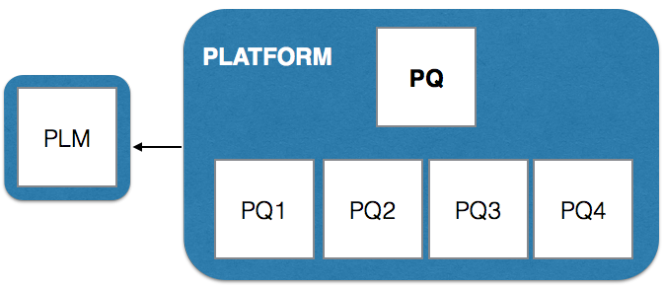

Figure 21 – The illustration of the case study regarding groups working with the perceived quality attributes.

4.5 Paper E

Purpose.

This paper presents extended data analysis and elaboration of perceived quality definition from the case study described in papers A and B.

The study investigates how the automotive companies communicate their core values to the customers, on which perceived quality attributes the companies focus, and the current and future trends regarding core values and perceived quality.

Table 3. Summary of key attributes from interviews

	Quality	Safety	Environmental care
VCG	"Luxury experience" Fit and finish Split lines NVH (noise, vibration and harshness) Craftsmanship Touch and feel HMI (human machine interface)	Innovative active safety systems Accident prevention	Minimizing carbon dioxide emissions Hybrid vehicles Drive – E powertrain
VT	Durability Reliability Robustness Gaps and flush Fit and finish Functionality Comfort HMI (human machine interface) Uptime	Reliability Maintainability Navigation systems Active and passive safety	Fuel efficiency Exterior design Low emissions Hybrid vehicles

Methods.

In-depth qualitative interviews were performed with senior management personnel. To understand how company's core values are perceived by the customers in practice, a quantitative survey was conducted with a number of Volvo car owners as well as semi-trailer truck drivers. Additionally, study presents the advantages of using Maximum-Difference Scaling (MaxDiff) method in comparison to the commonly used semantic-differential scaling (Likert scale).

The main results.

The study provides a detailed information about the perceived quality attributes, derived from the interviews with Volvo Car Corporation and Volvo Trucks professionals (see Table 3).

Notably, the definition of perceived quality in the automotive industry presented as follows: "*In the automotive industry perceived quality has a dualistic nature. The authors propose to see perceived quality as Value Based Perceived Quality (VPQ) and Technical Perceived Quality (TPQ). VPQ is about how the customers sense and experience product attributes and external product factors, such as brand heritage, core values and personal preferences. On the other hand, TPQ represents a more detail-oriented engineering approach that seeks to fulfill customer requirements and is driven by the internal industry competitiveness. TPQ incorporates a number of perceived quality attributes such as a dynamic structure, and the importance of these attributes can change over the time*".

Figure 22 – Key perceived quality attributes that are communicated to customers by professionals.

4.6 Paper F

Purpose.

This paper is an extensive review of the body of knowledge regarding the evolution of quality from the beginning of the 20th century. The paper chronologically and systematically describes major definitions of product quality, systems of quality, methodologies and assessment tools. It highlights the past and present vision of perceived quality as an aspect of the product quality in the manufacturing systems but also in the automotive industry particularly.

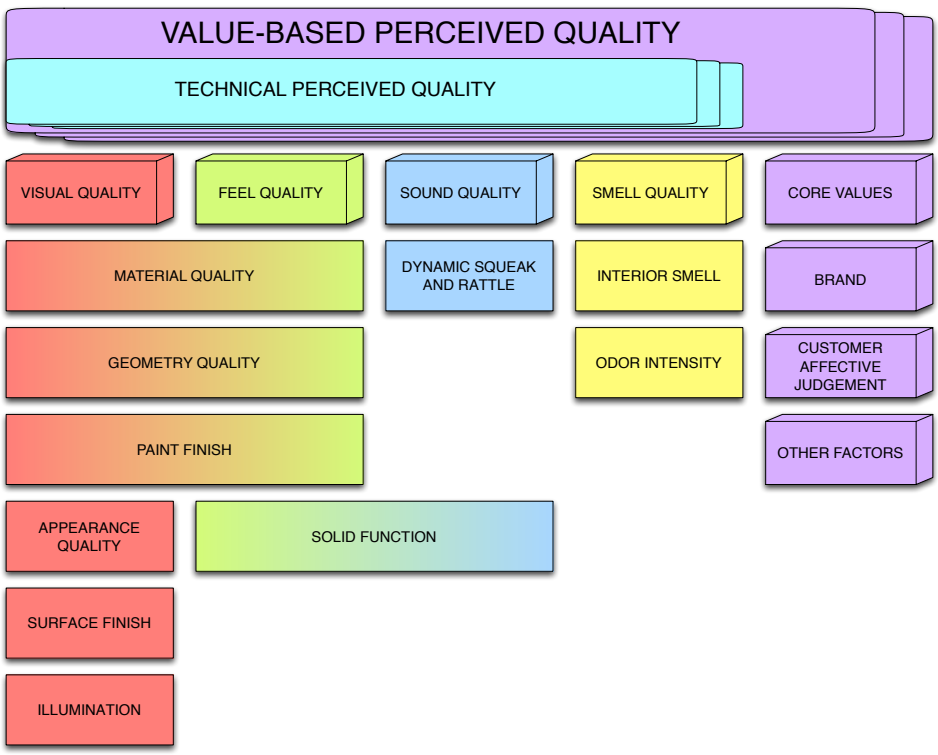

Figure 23 – The Perceived Quality Framework

Methods.

The in-depth literature review was performed to explore the issues regarding perceived quality and quality in terms of product development. The systematic searches of Scopus, WoS, Chalmers Publications Library (CPL), Google Scholar, SAE Digital Library for articles was performed with the particular attention to the automotive industry and product development. The key terms used in these searches were: automotive, perceived quality, product quality, iso, quality function, visual quality, sound quality, craftsmanship, brand, core values, haptic, feel quality, eye tracking, gaze, kansei, luxury, premium, NVH (noise, vibration and harshness).

After reviewing the vast amount of literature, it was classified into categories depending on the importance and nature of the research. The classification categories so chosen are: automotive quality, branding, core values, craftsmanship, eye-tracking, feel quality, Kano, Kansei, luxury and premium, method for perceived quality assessments, methods for translation of the perceived quality requirements into the specifications, NVH, perceived quality, product quality, sound quality, Taguchi, visual quality.

The data was coded and analyzed with NVivo – a qualitative data analysis computer software package.

The main results.

The study shows that perceived quality assessment methods evolved over the time, and evaluation of many of the perceived quality attributes can be objective. However, the existence of the knowledge gap regarding perceived quality in the automotive industry is shown, and evolution of the Perceived Quality Framework presented (see Figure 23).

4.7 Summary of the results

In brief, the results of all papers can be summarized as follows:

- The existing methods for setting up the customer's requirements and translation of these into the product specifications in the premium segment of the automotive industry is investigated (Papers A, B, E and F).
- The communication strategies and trends regarding perceived quality are investigated. It was demonstrated how the customers perceive and prioritize perceived quality attributes. The key discrepancies have been found and discussed regarding their implications on communication and perception differences between industry professionals and customers. This understanding helps to reduce the gap between the perceptions of professionals and customers, which can lead to improved product development for customer value and sales in these markets (Paper A, B and E).
- The extensive literature review rendered and presented certain confluences and disengagements in the definitions and terminology use. The existing quality systems and methods were carefully examined. This action allowed definition of new terminology framework of perceived quality for the automotive industry (Paper F).
- The comprehensive Perceived Quality Framework is introduced. The importance of perceived quality related aspects will only increase over the time. For this reason, the existence of a common terminology in the field is essential. Furthermore, the Perceived Quality Framework allows to structure perceived quality attributes for later assessment and evaluation (Paper C).
- The new definition of the perceived quality for the automotive industry presented. Previously, perceived quality was only defined from the marketing or limited product-based points of view (Paper E and F).
- Methods for structuring and integration of the perceived quality attributes for use in the design process, the concept of platform-based development and reusable platform elements has been introduced. As a matter of fact, it is a move towards definition and developing of methodology for capture and reuse of perceived quality related knowledge in the production systems (Paper D).

5 Discussion

This section aims to discuss the results in connection to the research questions. Additionally, the quality of the results in relation to the research approach will be discussed.

5.1 Answering the research questions

RQ1: *How can Perceived Quality requirements be defined and validated on a complete vehicle?*

About definition of the perceived quality requirements

The first part of the **RQ1** deals with the definition of the perceived quality requirements. There is a broad range of methods and tools for capturing customer's requirements and translation of those into the technical product specifications. Among those methods are: Product Semantic Analysis (Landauer, Foltz, & Laham, 1998), Semiotic Product Analysis (Opperud, 2004), Kano methods (Kano et al., 1984), Kansei Affective Engineering (Nagamachi, 2002), House of Quality (Hauser & Clausing, 1988), Focus Groups (Kitzinger, 1995), Conjoint Analysis (Green & Srinivasan, 1978), internal methods, derivatives and combinations of the above mentioned and many others.

However, there are a few weak points in the current approach of defining customer's requirements. First there is the question of smooth implementation and time. Most of the existing methods are rather time-consuming or have quite complicated procedure rules. In the automotive industry, the production cycle time has a clear tendency to decrease. This fact is the possible source of the conflicts.

Second, it is hard to capture customer's preferences with such a complex product like a premium car. Because of the high complexity, the customer is most often not aware of a majority of the product attributes that form perceived quality. As a result, it is hard to describe these attributes to the customer, to evaluate them.

Third, there is a limited number of players in the premium segment of the automotive industry. Consequently, some of the requirements are driven by the internal competitiveness and moderately related to the customer's actual needs.

Finally, perceived quality is expressed with the overall impression of the vehicle. It is a combination of all factors, attributes - tangibles and intangibles that form the customer's opinion. The biggest question at the stage of requirements definition is how to extract a single attribute and measure with the objective means its input to the overall perceived quality picture.

The author believes that the definition of the Perceived Quality Framework, presented in the **papers C** and **F**, and understanding of the perceived quality dualistic nature is the key to solving this problem. With the sensorial approach of the Technical Perceived Quality model, it is possible to define and evaluate objectively the majority of perceived quality attributes. Moreover, the clear and understandable terminology can contribute to establishing robust communication strategies at all levels of production, also between industry and academia.

About validation of the perceived quality requirements

The second part of the **RQ1** is mainly a subject of the future research. First of all, the case studies similar to one described in the **paper E** have to be performed with the different automobile manufacturing companies operating in premium or luxury segment. The comparison of methods and tools used among the companies will contribute significantly to the body of knowledge regarding perceived quality. Furthermore, the Perceived Quality Framework has to be enriched with the technical perceived quality attributes of the "ground" level and methods for robust assessment of these attributes.

RQ2: *How can Perceived Quality feedback from potential and competitor's customers be gathered?*

Getting the feedback, data collection

As was mentioned above, there is a range of the methods regarding data collection to receive feedback on the perceived quality related attributes. However, these methods need to be applied at the right time, in the right place. A holistic approach to the feedback gathering methodology is essential. The mixed methods approach so far appeared as a robust technique for gathering and analyzing the feedback. **Papers A, B** and **E** are a good examples of a mix of qualitative and quantitative methods. Notably, one of the methods used in the surveys is Maximum-Difference Scaling (MaxDiff), which is a quantitative choice-based technique used

for understanding a respondent's or a respondent group's relative valuation of different product attributes (Louviere, 1993). MaxDiff is used along with questions using the more typical sematic-differential scaling, which helps to detect a lack of discrimination and confounding among respondents (Magidson et al., 2009).

The incremental role of the big data analysis is a possibility to use crowdsourcing in the modeling and quantification of the perceived quality attributes (Ren et al., 2013).

With the qualitative data collection and analysis **papers B** and **E** present data received from the semi-structured interviews with the implementation of coding techniques and use of the qualitative analysis software NVivo (Welsh, 2002). The coding techniques were also employed in **paper F** with the Literature analysis.

Quite often a cross-disciplinary method implemented in practice in the automotive industry can bring valuable results. An example is the photo-elicitation method (Schaeffer & Carlsson, 2014), originally derived from ethnological research, can be successfully used in the customer studies along with the sets of structured or semi-structured interviews.

The future studies will include eye-tracking (Duchowski, 2007) as one of the methods for evaluation of the perceived quality attributes together with the semi-structured interviews. Eye-tracking was successfully used for assessment of Human-Machine Interfaces (HMI) and with the evolution of hardware it can be used for the vehicle's interior/exterior assessment.

RQ3: *What are the other techniques/functions and attributes which affect and correlate to Perceived Quality?*

Analyzing the results from all papers included in this thesis one clear conclusion can be made: Perceived Quality is a complex, multilevel construct that affects cognitive and sensory aspects of the human nature. Perceived Quality is a dynamic structure with interchangeable attributes that evolve over the time. The study presented in **paper B** has revealed the increasing role of the HMI as a perceived quality attribute. The vast development of the HMI systems will be expanded and developed even more in the future, and its role is expected to change from a supportive feature to an actively perceived quality component.

Perceived environmental friendliness of the vehicle also plays an important part in the customer purchasing decision both from the economical point of view and environmental care awareness.

Of course, superior technical quality in the premium segment of the automotive industry is an absolute prerequisite.

5.2 Discussing the results

To establish the quality of research, it is important to verify and validate it. The verification of research findings can be performed by Verification by acceptance and Logical verification. *Verification by acceptance* focuses on having new scientific contributions accepted by experts within the field. Research can be considered logically verified when it is *complete*, *internally consistent* and *externally consistent*.

Verification by acceptance

The papers included in this thesis have been a subject of a peer review process. P**apers A, B, C** and **D** were submitted to international conferences where the content was peer reviewed by the experts in the particular field. The results have been the subject of review and discussions followed by the podium presentations required to be published in proceedings of each conference. **Papers E** and **F** have been submitted to the scientific journals and are currently under the review process.

Moreover, the preliminary results of the research have been presented at the Wingquist Laboratory seminars with discussion including industry partners and have received positive acceptance. The theme "*Perceived Quality and The Future Cars: A Paradigm Shift*" after the selection process was accepted for presentation at the Design Society Young Members Event, ICED'15, Milan.

External consistency

The results can be considered externally consistent if they agree with established literature. The current research is based on the known quality models and literature. However due to novelty in terms of the relation to the automotive industry sometimes it is difficult to compare the results with different research centers. The author sees the proposed Perceived Quality Framework as an evolution of existing quality models with the particular application to the premium segment of the automotive industry.

Internal consistency

There are no conflicts between individual elements in the theory.

5.3 Research Quality in Descriptive Results

A qualitative approach and case study has been used in descriptive elements of this research. To ensure validity (Yin, 2013) proposes the following steps:

- **Internal validity**: ensuring the conclusiveness of the results. That is certain conditions are presented to lead to other conditions. The case study presented in this thesis aims to capture the perspective of the interviewees. Though the internal validity comes from the ability of the interviewee to communicate certain opinion to the researcher.
- **External validity**: establishing the domain of the results that can be generalized. The findings in the presented studies relate to the particular companies and cannot be fully transferred to other companies.
- **Construct validity**: establishing correct operational measures for the concepts being studied. The subject of analysis related to the studied companies and with the use of structured coding techniques presented descriptive information associated with the collected data. The transcripts have been reviewed and approved by the respondents.
- **Reliability**: a demonstration that the operations of study can be repeated with the same results. The semi-structured interview procedure to some extent can be influenced by the researcher, as well as coding procedure. However, the main outcomes would likely be similar to one presented in the thesis because of the descriptive nature of the study.

Additionally, taking Maxwell's approach of triangulation for results verification (Maxwell, 2012) the following conclusions can be drawn:

- the research was conducted at two different automotive companies, manufacturing a range of vehicles
- the interviewees were from various departments and have had different roles in the company. However, they had a holistic view of the processes due to their position in the company
- apart from interviews, numerous discussion with the industry professionals were performed together with a study of extensive literature and technical papers
- the results were presented in writing to peer-reviewing conferences and journals, as well as to experts at workshops and presentations

6 Conclusions and Future Work

This chapter presents the core of the thesis in terms of results and identified research challenges.

A general conclusion is that existing quality models are not yet all-covering, especially in the area of the automotive industry. There are certain confluences and disengagements in the definitions and terminology use.

The increasing importance of perceived quality forces the automotive industry globally to focus on the customer-oriented product development. However, the mechanisms and processes that trigger the customer's purchasing decision often remain uncertain. Today customer clinics and product experience studies are focused primarily on the determination of conformance of the product quality with the customer's expectations. These studies are expensive and time-consuming. Consequently there is a growing demand for robust methodology with the holistic understanding of the current and future challenges.

The Perceived Quality Framework presented in this thesis is a combination of the sensorial, measurable objectively Technical Perceived Quality and Value-based Perceived Quality that include attributes assessed cognitively. Technical Perceived Quality based on the primary human senses primarily provides an inclusive terminology framework.

It is a basis for developing new robust metrologies for measuring quality perception and finding the equilibrium of the importance among various perceived quality attributes.

Future research will more deeply investigate the concept of the perceived quality explored in this thesis, with the verification of current assumptions in industrial context and extending the aspirations with the ambition to create an all-covering, uniformed model for definition and evaluation of the perceived quality attributes.

Future work will also address the issues below.

- The additional case studies will be performed on various automotive manufacturers in the premium and luxury segment of the automotive industry, in order to foster and validate the Perceived Quality Framework and methods for setting up customer's requirements. That will allow presentation of an all-covering framework with the consideration of all perceived quality attributes.

- A cross-disciplinary study with the use of eye-tracking methods to determine an importance of the different perceived quality attributes to the customer.
- Support for the Perceived Quality Framework with the Meaning-Behavior Model.
- The composition of the methodology regarding objective evaluation and assessment of the perceived quality attributes. Finding the equilibrium of perceived quality at different product levels.

For future work, RQ1 requires further elaboration. The next stage of the research will also address additional research questions including "*How Perceived Quality can be differentiated between different markets?"* and "*How can Perceived Quality be differentiated for various vehicle types with the optimum customer value?"*

"Design must be functional and functionality must be translated into visual aesthetics, without any reliance on gimmicks that have to be explained." –

Ferdinand. A. Porsche

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