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The Assessment of Automotive Perceived Quality

By

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Abstract

We are visual creatures. We find ourselves immersed within perceptually salient environments, and routinely encounter items that we may propose to possess features that can evoke an emotional response. One of the principal factors associated with this dimension of visual aesthetics is how we perceive and value the innate properties relating to the quality of the artifact. Most people would recognize Perceived Quality (PQ), but few may be able to articulate exactly what it means. It is a state that we assign to products and services that involve some or all of the senses; most notably sight and touch.

The intended audience for this research is fellow Engineers, although the approach taken in the work is a multi-disciplinary one, whereby a psychological view is taken alongside pure engineering. As far as can be determined, this is a novel approach and has relevance to the manufacture and sale of any goods, not just automotive products and therefore has a real industrial application.

This research also considered what has been postulated on the subject so far. This was assessed within the confines of the automotive industry, as it struggles with the seemingly polar opposites of cost-reduction and PQ. It is a frequently-held industry belief that PQ has to be included in a project budget and raises the cost of a product, an issue which will be discussed in the thesis.

PQ is a continuous process across both product and service sectors. It never stops. An enterprise that does not measure, articulate or otherwise attend to PQ may lose custom. Such a commercial drive was incorporated into the research from the start and gives a real-world value to this thesis.

PQ is hard to define and unsurprisingly difficult to measure yet is the intangible force behind why we make many of our decisions when it comes to making a significant purchase. There have been several attempts to measure PQ, but these mostly amount to ratings that purport to indicate different quantitative dimensions associated with the construct of PQ. In order to better understand such a complex subject in relation to Automotive PQ, this research primarily adopted a qualitative method of assessment.

This thesis discussed product and manufactured quality and PQ scoring regimes based on simplistic number ranges and goes on to compare these current methods of assessment to a process that incorporated findings from three studies outlined in this thesis on firstly Engineers who create the PQ, then the OEM as custodians of PQ and finally the customer as consumer of PQ, at the same time inferring PQ. Analysis of the words used to describe PQ has been made from these surveys and themes developed. Two methodologies have been employed to analyse the assessment process.

The first use of ISM (Interpretive Structural Modelling) to look for relationships between attributes and see which, if any, is pre-eminent.

This is believed to be the first use of ISM to assess PQ attributes. These attributes are common to all three surveys but were focussed upon for the OEM exercise. The second methodology is the use of mental models to show how each of these three groups view PQ. What arose from the three experimental surveys was greater definition of PQ in its broadest sense, giving qualitative depth to such clarification and conceptualisation. The views of all parties along the PQ journey from creation to consumption has been canvassed and represented in simple word form and then in mental models.

Such a representation of the PQ concept is a multi-disciplinary approach and is believed to be the first publicly available research on PQ, combining an Engineering and Psychological viewpoint. The thesis focused principally upon verbalised articulations of PQ cues, but acknowledges there are others.

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This chapter was presented in Doctoral Symposium - Pogson, I. (2016) *The Measurement and control of Perceived Quality in The Automotive Industry*, Daventry and in '*Quality World'*, February 2016 (Journal of the Chartered Quality Institute), see Appendices 1.1 and 1.2.

Chapter 1 - Perceived Quality in the Automotive Industry.

1.0 The importance of Perceived Quality in the Automotive Industry.

PQ (Perceived quality) is the new battleground for sales of consumer goods (Stylidis, Wickman and Söderberg 2015). In the automotive industry there is keen competition amongst established players such as General Motors, BMW and Toyota and more recent global entrants such as Great Wall, Tesla and now even Kalashnikov have exhibited an electric retro-styled car. (Kalashnikov may be familiar as the weapon-makers of the AK-47 assault rifle).

It is expected that if professionals in any industry were asked the question "what is quality?" the outcome would be a variety of different definitions.Qualityitself may be defined as the standard of something as measured against other things of a similar kind; or a comparative measure of one thing against another. In Taguchi's seminal tome, *Introduction to Quality Engineering (1986:1)*, he proposes that quality "is the loss a product causes to society after being shipped, other than any losses caused by its intrinsic functions". This definition does not rely upon any subjective judgement of standards; just asks the question "does the item work correctly or not?"

Hoyer and Hoyer (2001) analysed the definitions of quality from the writings of eight quality gurus – Philip Crosby, W Edwards Deming, Armand Feigenbaum, Kaoru Ishikawa, Joseph Juran, Robert Pirsig, Walter Shewhart, and Genichi Taguchi.

They found their analysis of such writers gave them definitions of quality that fell into two categories:

1. *"A product or service delivered to a specification defined by metrics"*
2. *"Products and services that simply satisfy customer desires"*

However, other research has arrived at further definitions, affording weighting to different aspects of PQ. For example, Garvin (1984) analysing the work of various quality writers in this area, identified eight dimensions of quality, including such factors as reliability, durability and features. Interestingly, Garvin identified the final such feature to be *perceived* quality - PQ. More recently, the Chartered Quality Institute (CQI)defines quality as Governance, Assurance and Improvement in its 'Competency Framework' (CQI 2018). Further definitions of quality and PQ will be considered later in the next chapter on the complex nature and wide range of what is meant by automotive PQ.

1.1 Background

The background to this thesis is rooted in a commercial need at an Engineering Consultancy Company to know more about PQ, its definition and any measurement possibilities. When the research was begun in 2013, the Consultancy had made enquiries over a period of a year with Midlands-based tertiary education establishments to see if there was any on-going, relevant and accessible research into the subject.

Very little tangible, useful information had come forth, yet one major University had information and a course available on the subject, but this was not public and only open to employees of a major OEM (Original Equipment Manufacturer).

This precluded anyone from the Consultancy acquiring such knowledge. The Company therefore supported one of its own staff to begin this research and part-sponsored the student's efforts.

However, after less than 2 years of study, a Company re-structuring process meant that the student and employer parted, with the thesis author moving to another UK-based OEM.This change of employer enabled comparisons to be made between the two companies, who operate in differing segments of the market.

Both employers were willing to support the research as there were benefits for both, conditional upon access to the research.

One had a real hunger for PQ knowledge and the other supported a whole department dedicated to the subject. Each then had clearly different reasons for their interest and support, but this backing did in a clear and commercially valid way, support and endorse the research basis.

It is recognised by both Companies that PQ is a growing area for research, continually developing as the balance of vehicle ownership changes from outright possession to favour short-term leasing, Hire Purchase or PCP (Personal Contract Plans) and vehicles become more autonomous. (Where Level zero automation means the driver is responsible to operate the vehicle safely at all times, through Level 3 where the car drives itself and the driver is only required to take over if necessary to Level 5, fully autonomous).

PQ is an important subject because it has been shown to be a major differentiator between products and a key reason why people buy one product over another (Stylidis, Wickman and Söderberg 2018). PQ therefore holds immense commercial power.

Other people who consider that PQ Is worth investigating include leading marketing spokesperson Jan-Benedict Steenkamp (see Section 3.1.2), and a group of researchers in conjunction with Volvo Cars, fronted by Prof. Rikard Söderberg, Chair Professor in Product and Production Development at Chalmers University.

Also, there is an active group in the Laboratory for Machine Tools and Production Engineering WZL, RWTH Aachen University, led by Chief Engineer ADITEC-Gebäude, Björn Falk. This not an exhaustive list, but these are currently the most active and published.

Steenkamp for example, in his much-cited seminal 1989 book 'Product Quality' dedicated more than half of this volume to PQ (Steenkamp 1989).

The researchers at Chalmers and Aachen have produced many papers on very detailed aspects of PQ (Stylidis, Wickman et al. 2019, Wagersten, Wickman et al. 2011).

Recent work by these groups has been presented at mainly design-centred conferences as far apart as Stockholm in Sweden, Haifa in Israel and Vancouver in Canada (Falk *et al.* 2017).

Although there is such research available on PQ in the automotive industry and this is reflected in the Literature Review and Critiques, there was felt to be room to take that which was available and develop it using experience gained in nearly four decades of work at various locations, inside several companies and in different cultures of vehicle manufacture.

Years spent both at working and senior level in competitor assessment and in Company Quality departments gave access and insight to PQ on a real and practical level.

The subject was chosen because of its interest, relevance and technical difficulty. To achieve the aims of the research and capitalise upon unique access granted whilst working within the industry, it was resolved to survey two groups (Engineers and PQ Managers) with whom daily contact was possible and then a third group of customers. It was found that Engineers, even if they do not always realise it, create PQ and those who develop, manage and are custodians of a Company's PQ are also looking to continually update their knowledge. This led the research mainly along qualitative, descriptive analysis lines, rather than quantitative and statistical ones. One can argue that perception, emotion and the senses can in some way be quantified and a mix of the two approaches is contained herein. Such a qualitatively biased approach was deemed more appropriate to the study of a subject governed by perceptions, emotion and the senses.

The originality of this research comes from the unique access to two automotive companies, over decades of involvement in the Quality arena and a viewpoint shaped by such experience. Overlaid is a look into the psychology of PQ, thus taking a multi-disciplinary approach.

Although the standpoint is that of an Engineer within an Engineering company, sufficient exposure to many other Company functions and unparalleled real and close customer facing responsibilities allowed a broader view to be taken. This has enabled a standpoint closer to that of a future researcher in the scope of an experimental research effort.

Direct management of and involvement in Competitor Assessment, (to keep abreast of other OEM's products), Teardown, (to see how these are engineered) and Benchmarking, (to assess and set targets in automotive and other products) across many years also colours the research and gives it an exceptional edge from a viewpoint within the industry. These three areas are components of the PQ concept and will be considered in Chapter 4; they all tend to look at currently available manufactured quality issues, as well as design principles and philosophies.

1.2 Perceived Quality in the Automotive Industry – "what gets measured gets done"

The global Automotive Industry is fiercely competitive. It is an extremely risky venture through which to make money, as the price of entry is a competitive car which can cost around £1bn to design and develop and take up to four years to appear on the road (Shea 2010). This is before making any return on investment to recoup such a massive initial outlay.

During the four-year cycle of design, procure, build, test and improve, most manufacturers will have refreshed the product at least once a year and in some cases seasonally. As one vehicle is moving through the iterative process, another must follow closely. It costs a similar amount to develop a humble city car as it does a complex SUV (Sports Utility Vehicle), yet the returns are of course greater on the latter as it is presumed to have greater content and can be priced accordingly.

Often as well as product content and therefore price, PQ is an influential differentiator between market offerings. When the Lexus brand was introduced initially in the US and Japan the advertising was heavily slanted towards PQ. Although under the skin, the actual product was little more than a carefully built regular Toyota (this Author organised and attended Lexus product teardowns), it was rapidly perceived as different; a cut above. This was precisely Toyota's intent (Lexus UK 2015).

Some “innovative” touches, such as fluorescent speedometer and rev-counter needles were novel, the apparently “floating” instrument warning lights were merely projected reflections from standard masked incandescent light bulbs, but the effect was to raise the PQ above all else available at the time. Toyota’s initial claim that it would take them some five years to establish the brand was countered with their promise that by then they would be an accepted part of the luxury car scene. So, it came to pass, and Lexus is today regarded as a luxury brand of its own. In the UK, Lexus dealers won the Auto Express 2017 Auto Express Driver Power Study, which described them as “Britain’s finest”, (Lexus UK 2018).

For an up-to-date view of automotive PQ, a search of the Internet for the latest research shows that it also receives little coverage in either the UK’s premier Quality site (that of the Chartered Quality Institute – (CQI 2019), nor that of the American Society for Quality (ASQ 2019).

Searching for a latest PQ view through blogs, etc. reveals again very few entries. Most of those that do appear as ‘hits’ are often related to commercial enterprises looking to provide a quality or PQ measurement service to manufacturers, such as Dassault, Optis, ALG or J D Powers. One site, that of Marcus Roffey’s Perceptual Quality shows a date of 2012, so does not appear to have been updated recently (Roffey, 2012).

The following in Table 1.1 shows some commercial companies offering PQ measurement and definition.

Table 1.1. A selection of commercial companies offering PQ services (Author).

Company name	Service	Web-site
Dassault Systemes	CAD and IT-related engineering services, 3D design, 3D digital mock-up, and product lifecycle management.	https://www.3ds.com
Optis	Training, measurement, consulting, prototyping and VRT.	http://www.optis-world.com
ALG	Provide data, analytics and insights into the residual values of vehicles.	http://Alg.com
J D Power: JDP APEAL (Automotive performance, Execution and Layout) JDP VDS (Vehicle Dependability Study) JDP IQS (Initial Quality Study)	Provide ratings and research into vehicles	http://www.jdpower.com/cars
Perceptual Quality	PQ consulting	http://www.perceptualquality.com
NCBS (new Cars Buyer Survey)	SMMT UK Society of Motor Manufacturers and Traders)	https://www.smmt.co.uk/2005/07/new-car-buyers-survey/

Additionally to the listing in Table 1.1, various magazines or on-line surveys in each market offer their own version of UK publications such as “What Car”, “Car”, “Which”, etc. These tend to use similar star rating systems to compare one offering to another. Several automotive manufacturers, some of whom are shown in the next chapter in Table 2.5 surveyed for this research use similar measures in their rating systems. All of their schemes are in some way attempting to put some metrics on PQ. We shall now consider automotive PQ specifically.

More information on the detail of automotive PQ, definitions, OEM viewpoints, plus some current Quality and PQ auditing methods will be presented in the next chapter on the nature of PQ.

1.3 PQ, Engineering Psychology and Mental Models

Further to the previous definitions and search for a new way to explore and express automotive PQ and its measurement, both Mental Models and fuzzy language were considered. PQ, being the result of complicated thought processes seemed an ideal use for such models and the language used in describing PQ lends itself to fuzzy descriptors.

The search for specific PQ-related models brought forward only limited success and required new ones to be created. PQ and fuzzy language were also found to be a fallow field of information. The obvious link is there, but little evidence was found of researchers making this connection.

1.3.1 Human Factors and Engineering Psychology

In researching PQ, it is essential to consider Human Factors (HF). Human-Machine Interface (HMI), a sub-set of HF, is a term regularly debated within the industry, but is a whole thesis on its own. So, for this research, boundaries are set to acknowledge the importance and relevance of HMI and HF, but not to delve too deeply.

Human Factors Engineering came into being sometime post-WW2, when experimental psychologists were asked why serviceable aircraft were being crashed for no apparent reason and to investigate other military issues (Wickens *et al.* 2013).

Engineering psychology is itself a sub-set of human factors; the discipline considers the interaction of the head rather than the body's connection through limbs with the tactile world. The latter is more related to ergonomics, but this also has a strong influence upon PQ. However, the PQ relationship with the head is much more significant, which will be examined further in Chapters 4, 5 and 6.

It is therefore useful here to briefly consider how the brain functions and how mental models can be used to understand and represent these functions.

The STSS (Short-term sensory store) only holds information conveyed by our senses for seconds. Although a vast array of sensual information is registered all the time, only a fraction may be perceived, consciously and unconsciously.

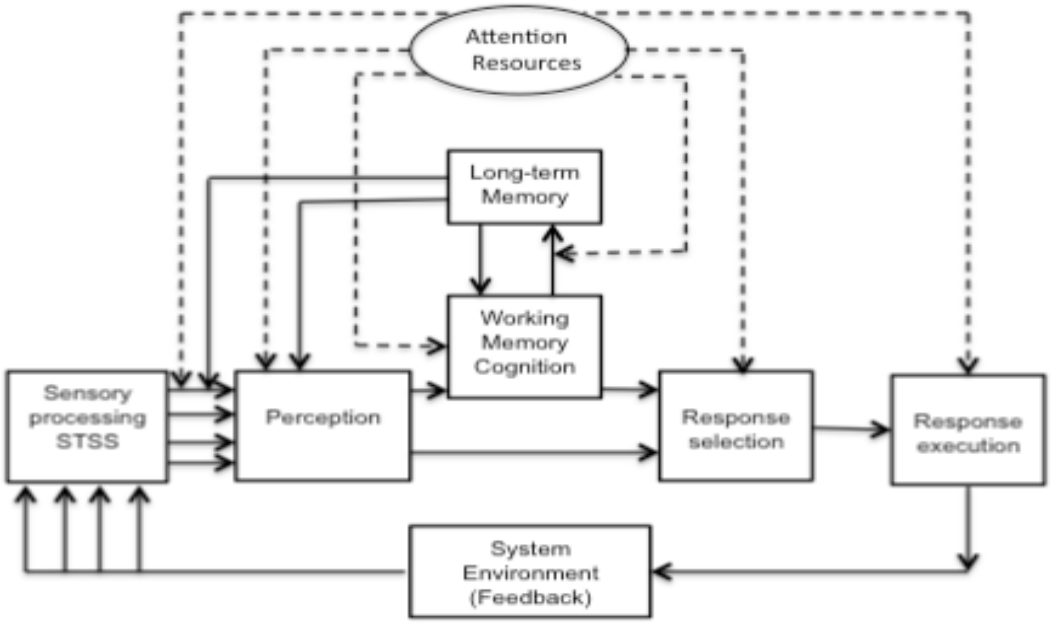


Fig. 1.1. Perception linking to attention, memory and response (Wickens*et al.*, 2013).

Perception involves associating a meaning with this information, which itself is coloured by past experience, such as a flashing blue light means the emergency services, as that experience is deeply-rooted in the long-term memory banks. Perception is followed by a response and/or a cognitive process which could precede a response, which is then executed as shown in the diagram shown in Fig. 1.1, “A Model of human information processing stages” (Wickens et al. 2013).

1.3.2 Mental Models

For this research, it is how to represent the perception of quality contained within Fig. 1.1 that is of interest here. Mental models are a useful tool to enable this representation.

Mental model theory is often expressed as Knowledge, Relation and Representation. “Mental models represent entities and persons, events and processes, and the operations of complex systems” (Johnson-Laird 2005: 187).
From this description, mental models would appear to be a good match for understanding and presenting PQ in automotive circumstances as simulations (Forbus, Gentner 1997: 1). In terms of PQ cognition and response as shown on the chart in Fig. 1.1, the brain uses its short-term sketch-pad of visual and other sensory devices to assess the product, such as echoic, (stored auditory information), iconic (visual sensory memory) and haptic (touch memory). The longer-term memory (perhaps from other products), feeds into the perception as directed by the arrows and a response generated. The brain can be thought of as a filing system – scripts (such as driving – not automatic, but close) or schemes (such as social norms for a meeting) are stored within to augment these responses (Wickens et al., 2013). An example of a pictorial mental model showing the general assessment of a car by someone upon first encounter is shown following in Fig. 1.2.

This figure below is a suggestion built up from years of personally assessing and organising the assessment of vehicles by others. It is a logical order in which a potential customer may view a car from first acquaintance.

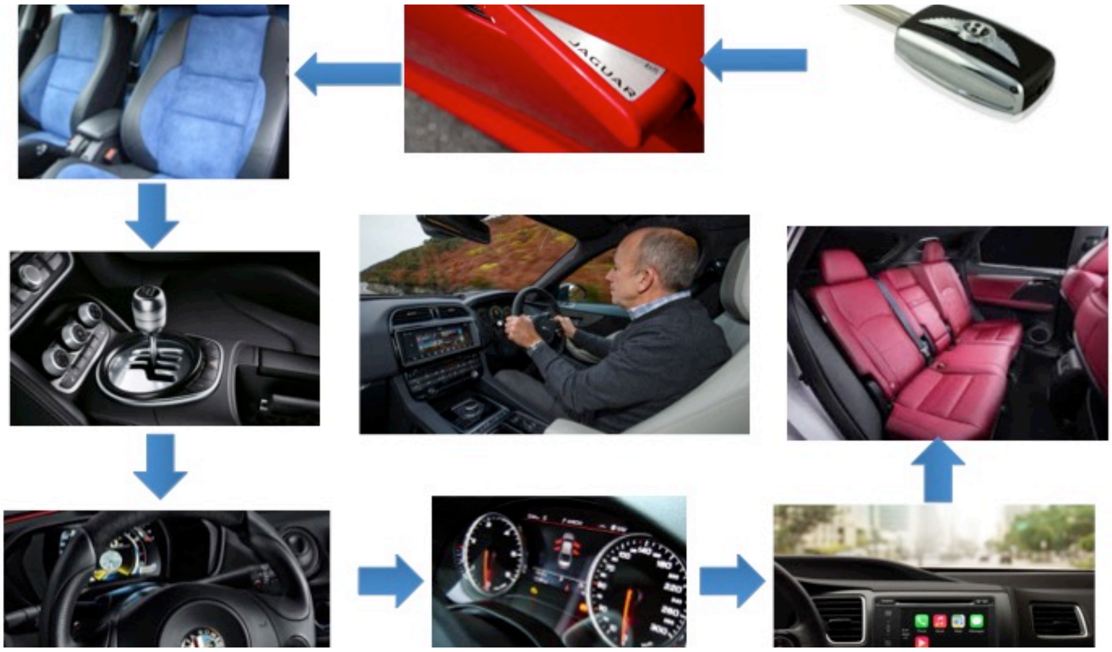


Fig. 1.2. The initial PQ assessment of a car (Author's suggestion).

Fig. 1.2 shows a suggestion of a mental model as a person approaches a car starting with the remote key fob as the initial tactile connection, walking to the car and 'handshaking' with the vehicle, i.e. operating the door release handle, opening the door and looking at the interior. This figure shows a parallel with Activity Analysis favoured by ergonomists.

Then, by regarding the centre console and gear lever, assessing the steering wheel, the instrument pack, any warning lights and then perhaps glancing to the rear seats, before actually driving, many complex PQ inputs are added up. All of this relates directly to the UX section that will be described in section 2.1.3. We shall return to mental models in the following chapters, as a principal methodology to aid the research.

1.4 Assumptions and limitations of the thesis

Assumptions made in the thesis are that PQ is a concept that many users may not be able to articulate or even recognise, but everyone who selects a product will make some PQ assessment in their head. They may be aware of doing this or not. This work will be limited to automotive PQ, as distinct from manufactured or product quality.

1.5 Problem statement: Research Question

Automotive PQ is usually measured by numeric means, for example 1 to 10, but this is hardly ideal, as one does not consider a product and decide to buy something with a PQ figure or measure of 6 or 8. PQ is something as we will see through the following chapters that affects many, if not all the senses.

So the problem, the Research Question is to discover if there is a more satisfactory method of assessing or measuring PQ than the current available means, which usually involve giving a numeric rating, to propose a more qualitative method for the assessment of PQ in the Automotive Industry.

1.5.1 Purpose, aims and objectives of research

The research purpose was to respond to a question set by an automotive OEM (Original Equipment Manufacturer) that was interested in finding out more about PQ. This is covered in more detail in Chapters4 and 5.

The aims of the research are to:

- Investigate an improved method to assess and measure PQ
- Evaluate mental models of what PQ means to customers/users

The aims will be addressed by creating three Surveys to cover the life of PQ, from its creation by Engineers to consumption by Users/Customers. PQ is a concept that is created, managed and consumed, therefore three surveys aligned to this concept's life-cycle are required. The data to back up this cycle will be provided by these surveys, one on each group. Most of the data will be verbal, descriptive and qualitative, although some quantitative analysis will be performed as well as comparative. Mental models will be created to show the thinking behind each group's survey outcomes. By examining the current PQ research and via these surveys it is planned to meet the aims above.

Research objectives:

1. Investigate and analyse various definitions of PQ.
2. Investigate and analyse the nature and various dimensions or constructs of PQ.
3. Consider and develop appropriate methodologies for the assessment of PQ.
4. Create a much wider view of PQ than previously seen in the public domain.
5. Adopt a multi-disciplinary view of PQ assessment, here meaning engineering and a psychological views.

1.5.2 Scope of the thesis and intended audience

This piece of work has been conducted part-time over the period October 2013 to March 2019, whilst this author was in full-time employment. It was commenced whilst in the employment of one company and concluded after employment with a second had also been terminated.

This allowed comparison between the two companies and their attitudes to the subject of PQ. As previously stated, this thesis will be limited to automotive PQ and will not include Service PQ.

Links to Perceived Value will be acknowledged, but again not covered in detail. The differentiation between strict manufactured quality which can be objectively measured, and PQ has already been discussed.
Automotive PQ is a wide field and has many influences which will be considered as the thesis unfolds. Human psychology and the senses are recognised in the following Chapters, but the main viewpoint taken throughout is that of Engineering, this being this author’s field of expertise. From a position within the Engineering Quality function, the usual automotive manufacturer’s departments or functions of Chassis, Electrical, Powertrain, etc. are characterised later in Fig. 4.1.
Therefore, the intended readership of this thesis is principally fellow Engineers.

1.6 Kano theory as a thread for the thesis

Noriaki Kano proposed his theory in themid-1980’s. It is summarised below in the familiar graph and will form a thread throughout this thesis. It is a quality tool that links to UX for example (User Experience, see section 2.1.3) and allows for analyses of such experience amongst customers, which ultimately can point at where investment in product improvements could be made(McCabe 2019, Verduyn 2014).Both Kano and PQ are heavily reliant on verbal statements, so there is significant common ground.

The graph in Fig. 1.3 is based on the assumption of three different attribute or factor categories: **basic** (must be present), **performance** (how the product achieves its objectives) and **delight** (over and above the previous attributes, often described as “unexpected”).

Time does however affect the movement between the categories, as customers become used to performance attributes and these become basic. Similarly, delight features over time become expected and degrade down into performance or even basic.PQ is strongly related to this model and it will be used as a linking thread throughout the research. PQ is directly concerned with such attribute categories and how they are perceived and experienced.

Figure 1.3 following shows the graph and the level of satisfaction with attributes and a product's achievement of them. There is also a 3-D axis of time, which must be overlaid on this 2-D graph. This is crucial to the continuing relevance of a Kano's work and is vital to the application of the model to PQ understanding.

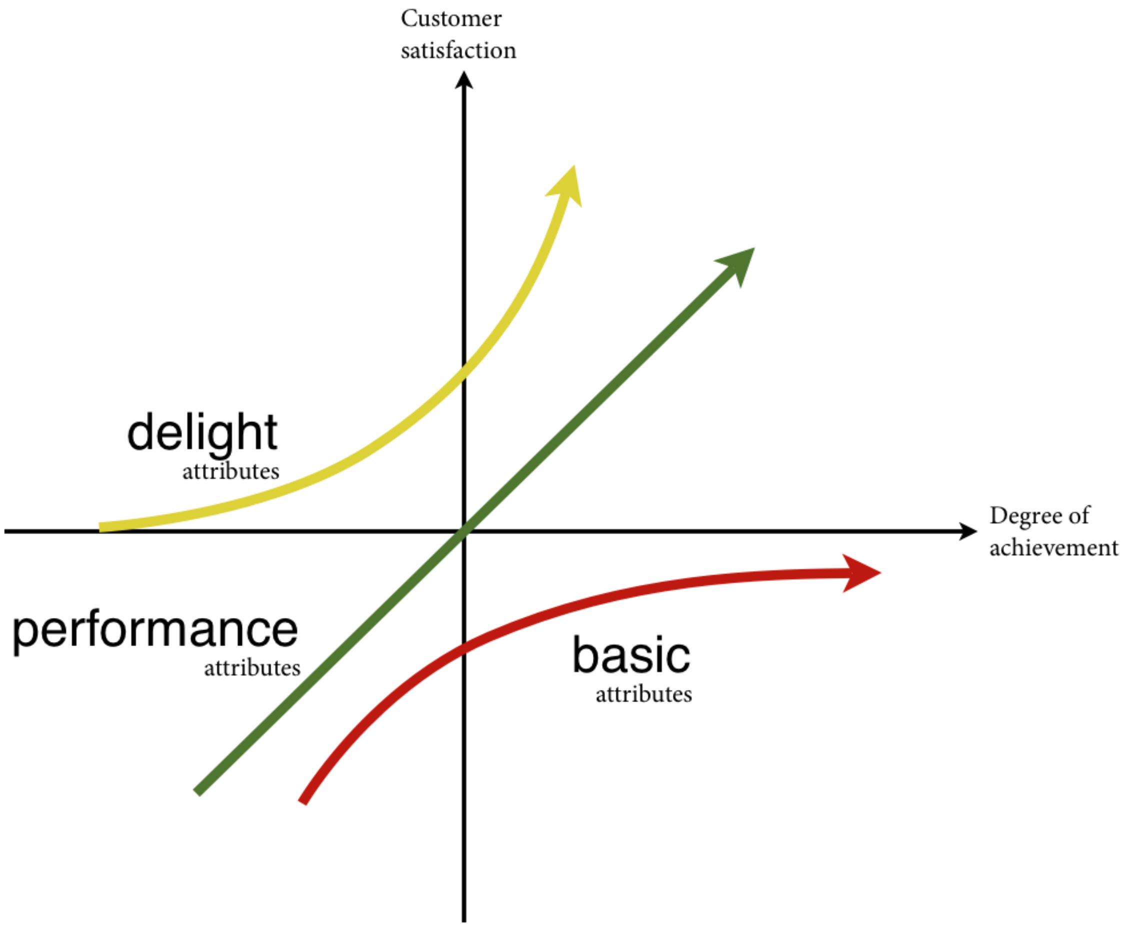


Fig. 1.3 Kano theory graph(Holst 2012).

1.7 Thesis outline

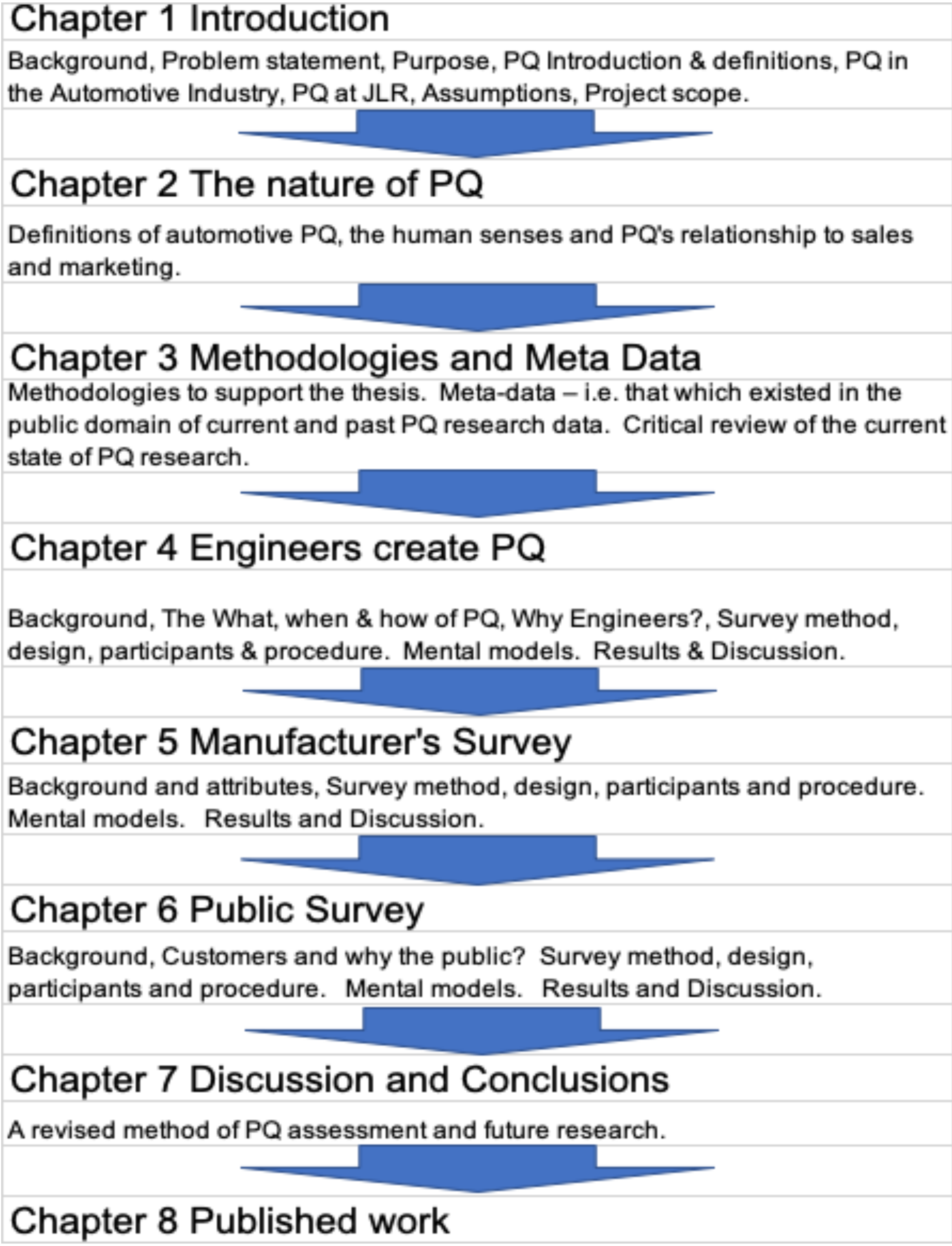


Fig. 1.4 Thesis outline (Pogson 2019)

1.8 Concluding remarks to this Introduction Chapter - next steps.

This concludes the automotive industry background to the thesis, rooted in a commercial need at an engineering consultancy. The importance of psychology and its role in understanding and forming views on PQ has been outlined. The unique nature of this thesis is the combination of a deep engineering background with a psychological parallel in trying to show a richer understanding of automotive PQ.

A full introduction to the wider meaning of quality and the more specific significance of PQ, with a narrowing down to automotive PQ, shown by several real-world examples, some further research on PQ and its nature, definitions, the relationship of sales to PQ, brand values and the human senses which assess PQ will follow in the next chapter.

Perception is all.
Customer perception is *<u>their</u>* reality.

Chapter 2 – The nature of PQ

This chapter will now consider PQ in its many forms, define the subject and give some closely related matters such as UX, Kano theory (as introduced in section 1.6) and the vital role played in PQ assessment by the many human senses.

2.1 PQ Introduction and definitions

We are visual creatures. We find ourselves immersed within perceptually salient environments, and routinely encounter items that we may propose to possess features that can evoke an emotional response. One of the principal factors associated with this dimension of visual aesthetics is how we perceive and value the innate properties relating to the quality of the artifact.

Most people would recognise Perceived Quality (PQ) but few may be able to articulate what it means. It is a state achieved by products that involves some or all of the senses, most notably sight and touch, from which we take our PQ cues.

This research focuses upon the automotive industry, especially cars and recognises that almost all manufacturers on the world stage have achieved some level of acceptable to excellent manufactured quality. The work will define PQ and separate it from manufactured quality sometimes known as product quality. It could be argued that some manufacturers have already achieved a high level of PQ although this is often related to brand, which will be mentioned in the thesis, but is a subject all of its own.

PQ is a widely-encompassing subject and although the focus of the research is automotive, a short example of a non-car-related but familiar UK landmark may serve to illustrate the significance of PQ in daily life. The London Eye, the world's tallest cantilevered observation wheel, was opened for the turn of the century UK Millennium celebrations in 1999. At its core is a massive hub bearing, manufactured by Škoda Engineering.

However, despite Škoda cars of the time such as the Octavia being well regarded, the manufacturer's logo was covered up as the hub assembly was floated down the Thames into position (Enright 2005; BillyT1903 2011).

It was thought by those in control that the 1970's and 1980's quality *perception* of the name Škoda was not suitable for the public to associate with such a brave, new structure (see Fig. 2.1 following).

This is the perception of quality, or PQ.

Fig. 2.1. The Millennium Wheel or London Eye (Dominici 2018)

(Upon cessation of hostilities, Škoda was nationalised by the Communist government, who divided the company into Škoda Auto and Škoda Engineering or Škoda Pilsen, which is still state owned, manufacturing railway rolling stock).

It must be pointed out that PQ is different to manufactured quality. Manufactured quality can be objectively measured through dimensional criteria. In order to sharpen the focus this thesis will limit itself to the PQ of manufactured products rather than the provision of services.

PQ however is not an exact science; it deals with how different people make their own individual assessment of a product (or service). Customers' utterances and how they deliver these views can be much more illuminating than bare quantitative statistics. Thus, PQ is also more about the emotive reasoning as to why an individual (usually the customer), likes or dislikes a product and makes a value judgement considering various indications (Steenkamp 1989: 107).

It is important to better understand the nature of PQ, as a simple response such as “like” can turn from an initial desire to an actual purchase.

Alternatively, a "dislike" can result in a product’s negative rating, which can in turn spread like wildfire across social media, as happened following the VW (and other OEMs) diesel scandal (Leggett 2018). PQ, according to an automotive study carried out in Germany, is a major purchasing criterion (Hamann 2009). It can also be defined as how the customer rates a product’s general merit or primacy (Tsiotsou 2006). The use of adjectives provides a means by which we can convey emotion about a product and how the product affects our lives. It is up to the manufacturer to be aware of the associated meanings attached to these words. Only by thorough PQ investigation can a manufacturer learn how to address their products to meet customer expectations. PQ can be impacted both by personal perception and the social environment.

Good PQ can turn a prospective customer into a passionate one, or if the quality is not what was expected, turn them away. Kataoka (2004: 381) described it as “a sense of quality that users actually feel when they see, touch and use a product”, while Petiot *et al.* (2009) defined it as multidimensional in nature. Fernandes & Alves (2012) explains that it “can be understood as the relation between perceptions and expectative, in other words, the difference between what the customer really receive (*sic*) and what he waited to receive”, (Fernandes, Alves. 2012: 2).

PQ is a broad church. By definition it’s based upon personal perception against a background of influences such as social media, although most customers could not effectively articulate responses to PQ cues. Therefore, there are as many definitions as there are perceivers. PQ could be viewed as the new battle-ground to win customers in the cut-throat automotive world.

It is vital to discover for any automotive company; to understand what contributes to PQ and what degrades it. In order to produce desirable cars, it is important to discover how PQ can be controlled.

Perceived quality runs across the entire creation process, starting in the design function, running right through to the receipt of the product or service by the customer, so the three surveys will address this flow.

This current research will consider what has been postulated on the subject so far. The subject will be assessed within the confines of the automotive industry, as it struggles with the seemingly polar opposites of cost-reduction and PQ. For example, many OEMs, such as Ford, cosset the driver with soft-touch materials within reach, yet rear seat passengers are catered for with hard, cheaper plastics.

2.1.1 PQ Conceptualisation and definition summary thus far

In looking for a definition of PQ amongst the many items of Literature which were read and are evaluated in the following chapter, several researchers were full of good intent, but shied away from achieving a succinct definition.

For example, one 2015 paper promised a definition within the Abstract section, yet despite proclaiming that "PQ is one of the most important factors underlying success of car manufacturers today" and proposing a common terminology and PQ definition for the industry, did not do so (Stylidis *et al*. 2015a: 1). Garvin was similarly vague in his seminal 1984 work by positing that of his eight 'Dimensions of Quality' the eighth, Perceived Quality, suggests that consumers do not always have complete product familiarisation or information and therefore pick up PQ from other influences, such as brand or advertising as in Garvin (1984) and social influences as discussed in this section. There follows a summary of definitions thus far:

- PQ is a person's perception through their senses (examined later in section 2.1.5). It is personal and affected by so many issues, such as brand expectations, education, culture, social strata and increasingly social media. Many of these will also be examined later. PQ Audits will be presented in section 2.2.2 and compared to manufactured or product quality as defined below.
- Manufactured quality is a result of many forces, not the least being capital spent on the manufacturing equipment and processes (Shea 2010). It is what comes out of the whole process and what is received by the customer (Shingo 1981, Shingo 1986, Taguchi 1986:1).

- This is also referred to as product quality in this thesis. Detail such as panel gaps and quality audits will be examined (2.2.1 and 2.2.3).
- Design quality is that which was intended by the original designer(s) and is executed through the engineering and manufacturing processes to create a product's aesthetics. Again, this will be examined later in this (Fig. 2.3) and subsequent chapters. Fig. 2.1.2 will show where the original, intended PQ 'escapes' during these processes.
- Attributes, those features or cues inherent in a product's design have been raised in the Kano model in section 1.6 and will be discussed further as the research unfolds. See section 2.3.

Importantly, PQ is a continuous process across both product and service sectors. It never stops. An enterprise that does not measure, articulate or otherwise attend to PQ may lose custom.

PQ is variously defined by the material covered in the following Literature Review in Chapter 3 and these are summarised in the following Table 2.1

Table 2.1. PQ definitions (Author's selection from Literature).

Researcher(s)	**PQ definition**
Aaker & Jacobson 1994: 192	"an intangible and do(*es*) not appear on balance sheets"
Böckenhoff & Hamm cited in Steenkamp 1989: 59	"The composite of all product attributes irrespective of whether these attributes are in reality existent in the product and objectively measurable, and whether consumers are correct in their evaluations."
Box 1984 cited in Steenkamp 1989: 58	"the degree to which a product fulfils its functions, given the needs of the customer."
Monroe & Krishnan in Steenkamp 1989: 59	"Perceived product quality is the perceived ability of a product to provide satisfaction relative to the available alternatives."
Ophius & Van Trijp 1995	PQ is a quadrant of Perception, Product, Person and Place. PQ changes over time. PQ is the end and attributes are the means. PQ lies between a Zen approach and objectives. PQ has a

	multi-dimensional nature.
Reese 2015	"PQ is a major business trend, it is Look, Feel and Touch."
Steenkamp 1989: 99	"…perceived quality is fitness for use."
Stone-Romero, Stone & Grewal 1997: 87	PQ is: 1. Flawlessness 2. Durability 3. Appearance 4. Distinctiveness
Stylidis, Wickman & Söderberg 2015: 166	PQ comprises TPQ and VPQ (Technical Product Quality and Value Based Perceived Quality).
Yee & San 2011: 49	"PQ is the degree to which a product or service provides key customer requirements (customization) and how reliably these requirements are delivered."
Zeithaml 1988: 3	"PQ is not the actual quality of the brands or products, rather, it is the consumers' judgements about an entity's or a service's overall excellence or superiority".

Unlike quality itself, PQ does not benefit from a dictionary definition; the above definitions in Table 2.1 show how varied are the views on PQ. We shall now consider the conceptualisation of PQ and some further possible definitions.

All enterprises are governed by standards, so the following section shows a link with ISO Standards of quality and the customer, as it would be remiss not to mention Quality Standards in this research.

2.1.2 ISO (International Organisation for Standards) Definition

Although there is no mention of PQ in the Standard, ISO 9000:2015 describes the essential concepts and philosophies of quality management –

"…..which are universally applicable to the following:

1. organisations seeking sustained success through the implementation of a quality management system;
2. customers seeking confidence in an organisation's ability to consistently provide products and services conforming to their requirements;
3. organisations seeking confidence in their supply chain that their product and service requirements will be met;
4. organisations and interested parties seeking to improve communication through a common understanding of the vocabulary used in quality management;
5. organisations performing conformity assessments against the requirements of ISO 9001;
6. providers of training, assessment or advice in quality management;
7. developers of related standards." (ISO 2015: 1)

It is principle 2 above that gives an internationally standardised approach by implication to the subject of PQ, with conformance to requirements an oft-quoted definition of PQ, as in point 2 above. Principle 3 also implies PQ, as the latter, especially in the automotive industry relies upon suppliers recognising PQ in their product and seeking to improve that.

The Standard, first published in 1987 was based on a British Standard, BS5750 from the BSI (British Standards Institution), but its roots can be traced back to a US Military government procurement standard, MIL-Q-9858 of 1959 and the U.K.'s Def. Stan. 05-21 and 05-24. The point of such an international agreement as ISO was to help suppliers to multiple customers meet one standard rather than several and so increase competitiveness, improve transparency and reduce waste. This, however, remains the only relevant standard to PQ, so we must look further for a definition.

2.1.3 The Design and Emotion of PQ

Design and emotion are closely associated with PQ and are covered in some detail by some commercial PQ measurement companies, such as J D Power (Power 2016).

However, from the academic side of PQ research, the PQ element within Steenkamp's model is linked to research carried out at Delft University, which has taken the step of connecting Design and Emotion across various disciplines and industries and had formed the Design and Emotion Society (Hekkert 2017). These two subjects had been the background to ten successful conferences across the years from 1999 to 2016 (Hout 2018).

Considering all the research reviewed for this thesis, one piece by Desmet, Fokkinga, Hekkert, Hassenzhal and Özcan (2014), closely corresponded with elements raised in PQ.

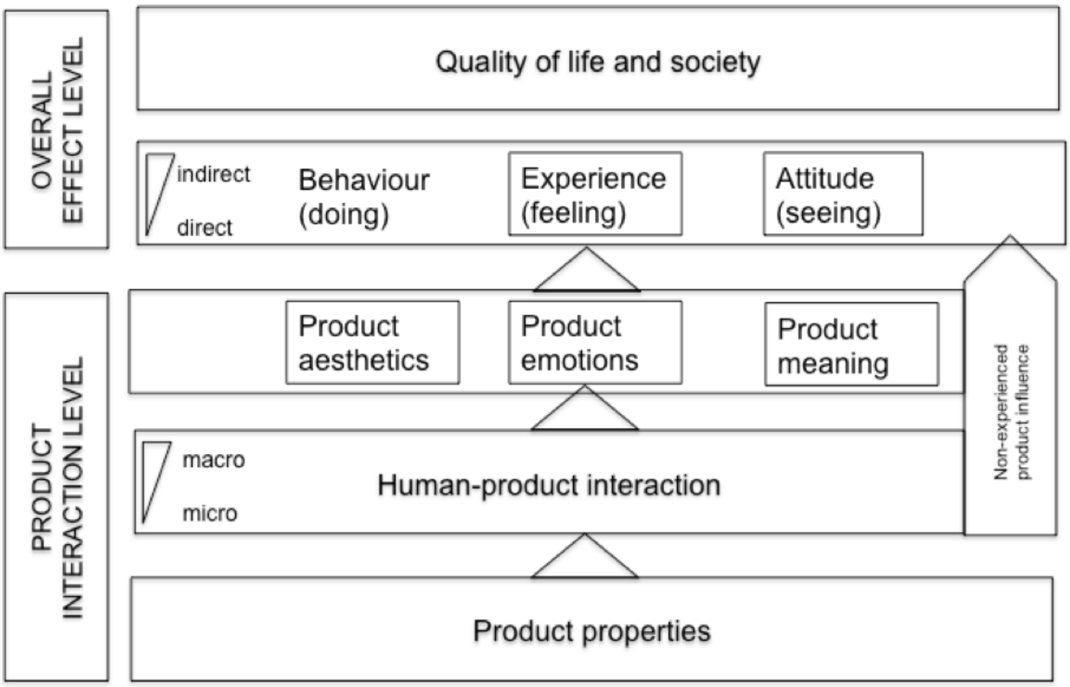


Fig. 2.2. The Product Impact Model, taken from Fokkinga *et al*, (2015)

It had culminated into a tool called the 'Product Impact Model' (see Fig. 2.2*)*. However, it was also clear that the research which had been built up over a number of years was incomplete.

Emotion has always been seen as a core of vehicle purchase (hence marketing campaigns regularly try to appeal to the emotive side of human behaviour, (see section 2.2.5) so this was an avenue to be investigated to see if it linked to PQ.

This model was proposed by Fokkinga, Hekkert, Desmet and Özcan (2014).

They presented a pragmatic model of how users interact with products, covering experiences, emotions and resulting behaviour. Building from earlier work (Desmet and Hekkert 2002) a user-product interaction model was created, enabling product analysis to be conducted but with more data gathered to define the still subjective views. The paper aimed to give some insight as to how products impact upon users. This might help designers understand product use and implications, by considering product experiences and effects.

The research covered a simple “division of user experience and behaviour into three elements” (Fokkinga, S., Hekkert, P., Desmet, P., Özcan, E. 2014: 10). The Model works as a reflection of real-life product experiences. Involvement with a product is in layers, which intertwine and complement, where experience and behaviour cannot be separated.

Pogson (2016) took the research model one step further by adding an additional dimension – that of the participants’ background and education and by using the model as part of a wider version of automotive PQ, as presented in Chapter 6 on the customer of PQ and shown in Fig. 6.4.

There are many other writers/practitioners active in Design and Emotion, perhaps most notably Don Norman, a co-founder of the Nielson-Norman Group and a psychologist/cognitive scientist/design theorist. An interview with Norman by Mark Blythe and Marc Hassenzahl (co-creator of the Product Impact Model) was published in October 2004. This considered design and emotion. Johnathan Chapman is also very active in this area (Haines-Gadd et al. 2018)

2.1.4 UX (User Experience) and Empathic Design

Mention must be made here of the field of UX and Empathic Design, putting oneself (often as a Designer), in the shoes of a user or customer.

There are strong links among researchers themselves and their subject matter with UX, Design and product quality (Hassenzahl 2009; Pettersson and Karlsson 2016). It is not intended to divert into a deep study on UX and Empathic Design, just to acknowledge the strong connection with PQ.

Design is an experiential issue, so through studies such as UX and trying to understand the mind of the user/customer or gain empathy with the latter there is much detailed research available ((Barrett, Burns, & Evans, 2002) (Kouprie and Visser 2009)

UX is an attempt to assess the interaction between product and user but focuses on the person – the 'user' of the product. It is very current time-biased, where joy and hurt play a central role and come from attempting to fulfil basic human needs (Hassenzahl 2009: 4). UX has a central tenet of looking at the user interaction and ensuring the user gets what they want with little frustration and not just the performance of the product in use (Hassenzahl 2009). In general, it is widely agreed that UX has three main stages – Acquaintancing, Using and Transforming (Pettersson and Karlsson 2016).

The origins of empathic design can be traced back to 1873 and art history, where the concept of "Einfuhlung" or "feeling into" was postulated by the works of Johann Gottfried Herder, then later by other German philosophers, Robert and Friedrich Vischer and Theodor Lipps (Nowak 2011). The term "empathic design" can be traced to the late 1990's when it was postulated that designers in Sales & Marketing, Engineering and Product Design need to be more sensitive to their customers/users and create things of use and enjoyment for people they may never meet. This means placing themselves into the shoes of the customer or alongside them.

Empathy can be described as a quality of creation in design, a question of immersing and internalising, then projecting (not judging) customers' needs.

Four phases of empathy are described by Kouprie and Visser (2009) as: -

1. Discovery – entering the users' world – achieve willingness
2. Immersion – wandering round in the other's world – taking user's point of reference.
3. Connection – resonating with the user to achieve emotional resonance
4. Detachment – leaving the user's world – design with user's perspective.

Empathic design was developed to stimulate innovation and may be defined in terms of what actions are recommended for a designer to take in order to meet user demands.

Barrett, Burns & Evans (2002) developed key guidance for designers in this area, in the form of "The 10 D's", shown in Fig. 2.3. The steps "Don't just ask", "Design is for life", "Delight your customers" and perversely "Don't focus on the product" seem to be closely associated with PQ.

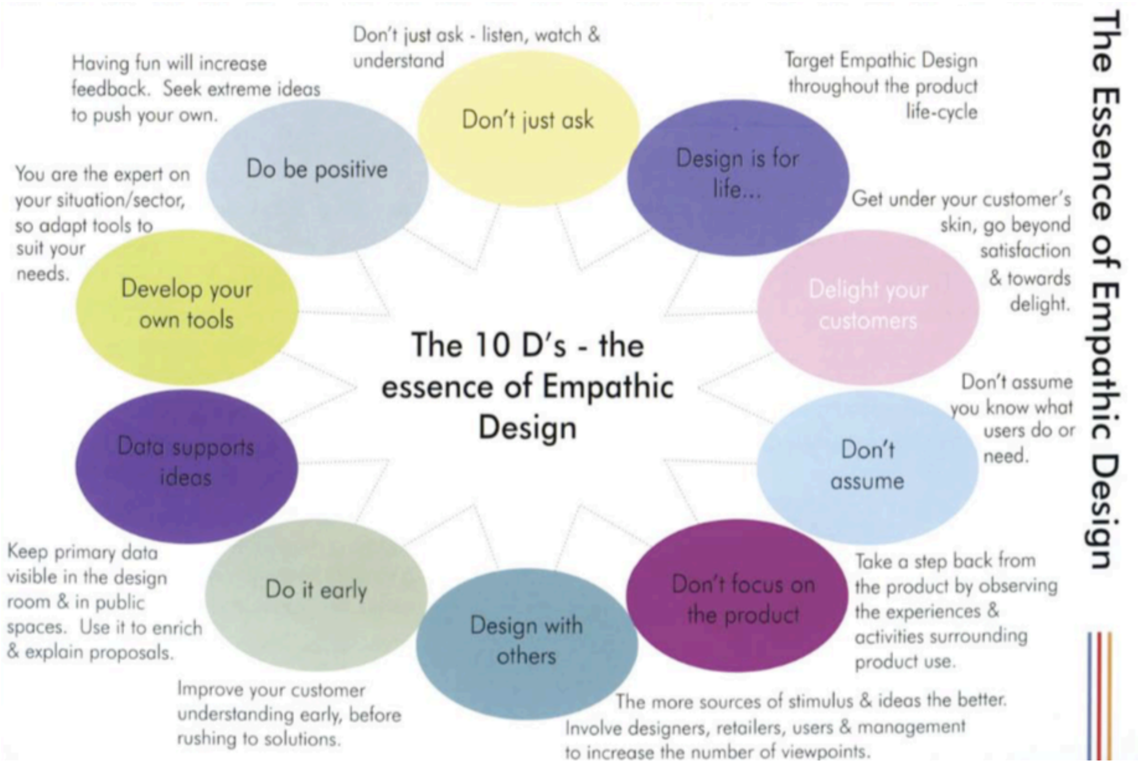


Fig. 2.3 The 10 D's of Empathic Design (Barrett, Burns and Evans 2002)

2.1.5 The senses and their role in PQ assessment

Steenkamp (1989) uses the word "cue" and the phrase "perception process" throughout his work and these are assessed by humans through the senses. This section is meant to serve as a brief recognition of the indivisibility of the senses and PQ; the subject of PQ is assessed entirely by the senses. It is by no means a complete review, but an acknowledgement of their vital importance to PQ assessment.

The principle of five basic human senses is often traced back to Aristotle's *De Anima* (On the Soul), which could be argued is the classic model of just five senses. Aristotle's studies looked at vision, hearing, touch, smell and taste.

This modern thesis will not attempt to do any more than acknowledge the existence of other human senses, such as those that inform us of the position of our bodies, known as proprioception. This sense comes about from receptors in our muscles known as spindles, which inform our brain about the present length and stretch of the muscles.

The body can even monitor our position relative to gravitational pull, where the information is provided by fluid within the ear. Fairground rides trade upon these senses to generate a feeling of giddiness and fun.

The vestibular system is responsible for our sense of balance. Driving cars and riding motorcycles in particular use these senses continuously. It could be argued that we have just three senses – mechanical (including touch, hearing and proprioception); chemical (covering taste, smell and internal senses); and light (Jarrett 2014). A fuller review of the senses and their pivotal role in PQ assessment is shown in Appendix A2.1.

Further to the preceding sections on UX and the senses, it is possible to directly interview the public or real customers at open events, but experience dictates that this is time-consuming and entails imposing oneself on a person who is not necessarily attending an event to give their opinion via surveys. Working at motor shows and other gatherings of cars and prospective customers has confirmed this. This is unfortunate, as what is known as "customer murmur" is often overheard at such occasions, i.e. what the customer *really* thinks in terms of using their senses to gauge and articulate UX and PQ.

Having conducted surveys on motor show stands, it became obvious that the interviewee often felt trapped or uncomfortable, as they always (and rightly) assumed that the point of the survey was to encourage them to engage with or buy the product on show. Even at gatherings of self-confessed 'petrol-heads' at motor racing events or specialist shows, the potential customer is (in the UK at least) somewhat uncomfortable responding to unexpected surveys face-to-face.

Apart from natural reticence, ill-defined attributes are an issue for such confrontational approaches, so the following sections will examine PQ and these attributes in more detail.

2.1.6 The What, Why, Where, When and How? of PQ

Whilst working at a global vehicle manufacturer's Technical Centre/Consultancy, this study of PQ in the automotive industry was initiated, to study the "What is PQ" question. The manufacturer itself was at the time quite a new entrant to the market and although it had long experience working with established global players, it had set out to design and develop its own brands and ranges of vehicles and therefore its own PQ understanding and stance.

Initially, the commercial imperative was to sell cars to make a return on the massive up-front investment made in personnel, plant and equipment. In such an industry, the costs for and engine plant alone can be hundreds of millions of pounds (Brooks 2017).

The "Why PQ?" question can be shown by the sheer amount of money that is spent by the OEM to create their products and generate manufactured quality that is a basic customer expectation, with PQ being the extra on top of this that the manufacturer believes the customer will pay to buy their products over a competitor (Falk *et al.* 2017).

Any new manufacturer and entrant to the worldwide automotive market must decide on power plants for the products (traditional internal combustion engines or hybrid/electric power or fuel cells, the first of which can be bought from established manufacturers), a body and paint plant and a final assembly and trim facility. Large parts of a vehicle can be and are, sourced from specialists, or made by the OEM. Some companies, such as BMW have specialist facilities such as the Hams Hall engine plant near Coleshill in England and then supply multiple vehicle assembly factories around the globe (BMW 2017). An engine plant such as Hams Hall costs hundreds of millions of pounds.

This particular manufacturer had created a new engine plant, co-located with its body, paint and final assembly facilities. This harked back to the days of the Ford River Rouge plant in Detroit, the Ford UK Dagenham complex, VW in Wolfsburg, Lower Saxony, Germany, Toyota city in Aichi Prefecture, Japan and the Austin works at Longbridge in Birmingham, UK.

This was an unusual chance to take in the first decade of the current millennium, but has been a success, although world, national and local economic change has meant that its profitability has meant new, or later facilities being located elsewhere in the interior of the host country. Once established and product was being made and sold, the company efforts were concentrated upon achieving in the first instance nationally acceptable levels of product quality. International sales followed.

The achievement of world-class standards took some time longer and required the input of a UK consultancy to teach, inform and coach employees to improve their performance. Later on, in the cycle of developing this fledgling operation, interest began to develop towards PQ.

It could only be understood as time moved on after some product succeeded in some markets and others did not fare so well in others. Questions as to why this was so were naturally asked and low or misunderstood PQ was cited as one of the possible causes for low sales. Therefore, the desire to learn more about the subject became apparent and the Quality function were consulted as to the latest PQ thinking.

“Where PQ” was demonstrated again in this Company, as PQ had been studied for many years in the UK arm of the Company and attempts to convince leaders of its place and importance were made, but until there was a ‘pull’ on the subject, the Quality department had been merely ‘pushing’ the concept, measuring competitor cars (i.e. manufactured quality) to establish benchmarks (targets) and had been politely listened to, but not really heard. With three main Engineering and production centres in three countries, along with input from independent design/styling houses, the time had come for PQ to be taken more seriously.

An unfortunate and unexpected dip in domestic sales also caused the Company to look to PQ and its role in encouraging customers to buy the product.

The UK operation had much experience in PQ, as many of the Design Engineers had worked for established global players in the industry and individually carried this information in their brains, yet little of it was known, widely recorded or accessible by others. Day-to-day pressures of designing parts and systems, then releasing these properties took precedence over ‘soft’ issues such as PQ.

It was therefore decided to attempt to tap into this anticipated pool of knowledge through asking the population of Engineers for their views.

In the absence of suitable Human Factor experts, a survey was seen as a suitable method to capture information, as most employees were used to such devices in their personal lives and also all were on-line connected. So, a modern-looking survey with a very personal, yet company process-focussed format was appropriate. It was not to be too taxing, take much time and be a maximum of 15 questions. In the case of this survey, the “When PQ?” question was demonstrated in this first survey and investigation into the role of the Engineer in PQ Creation.

It had been noted by Wagerston *et al*, working principally in Volvo Cars that PQ is created by the Design Engineer(s) (Wagersten *et al.* 2013, Stylidis, Wickman and Söderberg 2015, Reese 2015). This in-Company survey found similar results to that of the work in Volvo. The detail and results from the survey will be expounded upon in Chapter 4.

2.2 Automotive PQ – what is it? An OEM viewpoint

PQ is a complex, emotive and subjective topic but has been shown to be a significant factor that underlies the purchase of an automobile (Tsiotsou 2006). Such a key aspect of decision making, which has a critical component on commercial behaviour, requires better understanding.

The following is the analysis of PQ according to an OEM, whose identity must be confidential.

Automotive PQ is a construct in three phases:

1. Research - Initially the vehicle will be judged
    a. in advertisements (print or online)
    b. in ‘the metal’, at a dealership, show or on the open road
2. The Dealer visit (although many manufacturers take orders online and deliver to the customer. This has been possible in Japan for many years).
3. The Usage, or ownership experience

For a customer visit to a dealership, an assessment is made. Two types of decision are taken, initial and secondary:

The initial decision is made in seconds using main senses (see Appendix A2.1). This is a subjective appraisal by the customer using emotion, using the heart. This is where PQ has its greatest influence.

Secondary decision is influenced by cost, financial package, warranty period etc., using the head.

The main senses are used thus:

Sight - Immediate visual appraisal - vehicle appearance, attractiveness, colours

Touch - Tangible tactility, sensing robust, pleasing surface characteristics

Smell - Welcoming - leather smell (in Western markets), cabin freshness, newness, or lack of odour in the Chinese market (E&T Editorial Staff 2017).

Sound - Robust, solidity, e.g. door shut, door lock, reassuring quality

Function – Precision, e.g. all controls, rotaries, closures (doors, lids, etc.)

Other senses are involved, please see the later Appendix A2.1 section on Human Senses.

As the senses assess a vehicle, normally it is divided into three main industry-recognised zones as shown in Table 2.2 following:

Primary – aimed at the driver

Secondary – for the passengers

Tertiary – Floor and luggage areas.

Table 2.2. Automotive PQ Zones

Zone	Areas in Zone	Features
Primary	The key fob Instrument pack topper pad and trim Steering Wheel and trim Binnacle dials Gear knob Seat and trim HVAC (Heating, Ventilation, Air-Con) and ICE (In-car Entertainment) controls	Higher cost materials, with good tactility
Secondary	IP lower including glove box, IP end and closure panels – use hard plastics Handbrake (ergonomically a primary zone) Floor console Door casings, inner release handles and arm rest	Lower cost materials, but with good grain and gloss levels.
Tertiary	Carpets and mats Main Luggage Compartment (Boot) Engine or secondary luggage compartment	Durable materials, good functionality

Appendix A2.2 shows a breakdown of these Zones shown in Table 2.1 into detailed PQ analysis fields and issues upon which assessment can be made. Written permission has been granted to re-print the breakdown, but the identity of the supplying company is confidential.

However, discussions with industry colleagues from automotive OEMs reveals that these issues are very common. Nonetheless, these criteria are the ones which have been used for PQ scores shown elsewhere in this thesis. Where possible, academic references have been added to show evidence for these criteria.

Following in Fig. 2.4 is an observed list of vehicle primary points of contact taken during a simulated pre-road test study at a dealership conducted by an automotive engineering design consultancy May 2014 (10 participants). They can also be seen and sometimes overheard, at any car hire outlet, or a motor show. These are the "Customer" points of contact, in a suggested order of events (for a stationary vehicle). Although primarily geared to assessment of a car, these could equally apply (with some tailoring) to a van, coach, lorry or even a motorcycle.

Many customer PQ assessments will be made online, where sophisticated techniques which are beyond the scope of this thesis would be required.

It is also recognised that decision-maker and driver can be different, an issue encountered in the Customer survey in Chapter 6. Complex decision-making relationships affect PQ.

Aspects that traditionally belong to other attributes like ergonomics, maintenance, HMI, UX etc., are included in the PQ scoring. In the automotive industry the definition of PQ could vary between OEMs, but it has a quite solid definition and limitations.

PQ is definitely associated with engineering aspects that can be controlled. However, in academia PQ could span from marketing aspects to pure engineering aspects like gap and flush. It is summarised as a series of steps in Fig. 2.4 following.

PQ cues are not restricted to those in the automotive arena, but this research will focus on these, as access to them was guaranteed and the initial commercial driver was automotive. What follows is a representative PQ evaluation and may not be best practice but was extant within four of the top global automotive companies.

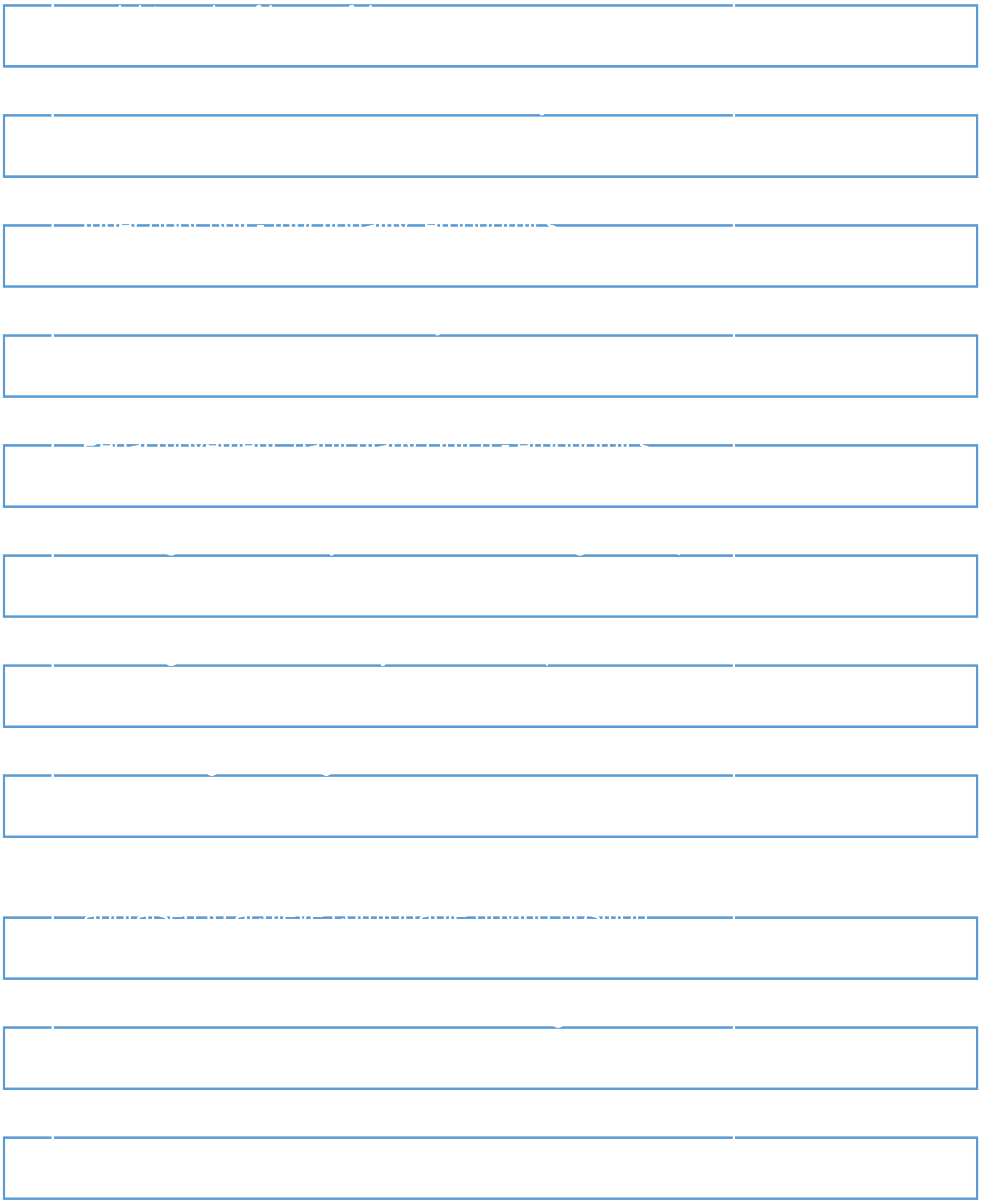


Fig. 2.4. PQ flow upon first acquaintance with a car (Industry observations)

Fig. 2.4 above shows a suggestion of a person’s first acquaintance with a vehicle and its resultant PQ impression. It can be observed in any automotive dealership.

The preceding flow-chart in Fig. 2.4 gives one view of the possible thought processes, visual, tactile and functional inputs to a person acquainting themselves with a vehicle for the first time. The process could stop at any point and deviate into dissatisfaction or interest as the person becomes either less inquisitive or enjoys the product more. A revised version would apply to other vehicles, such as a motorcycle. For a vehicle, these could be shown as below in Fig. 2.5.

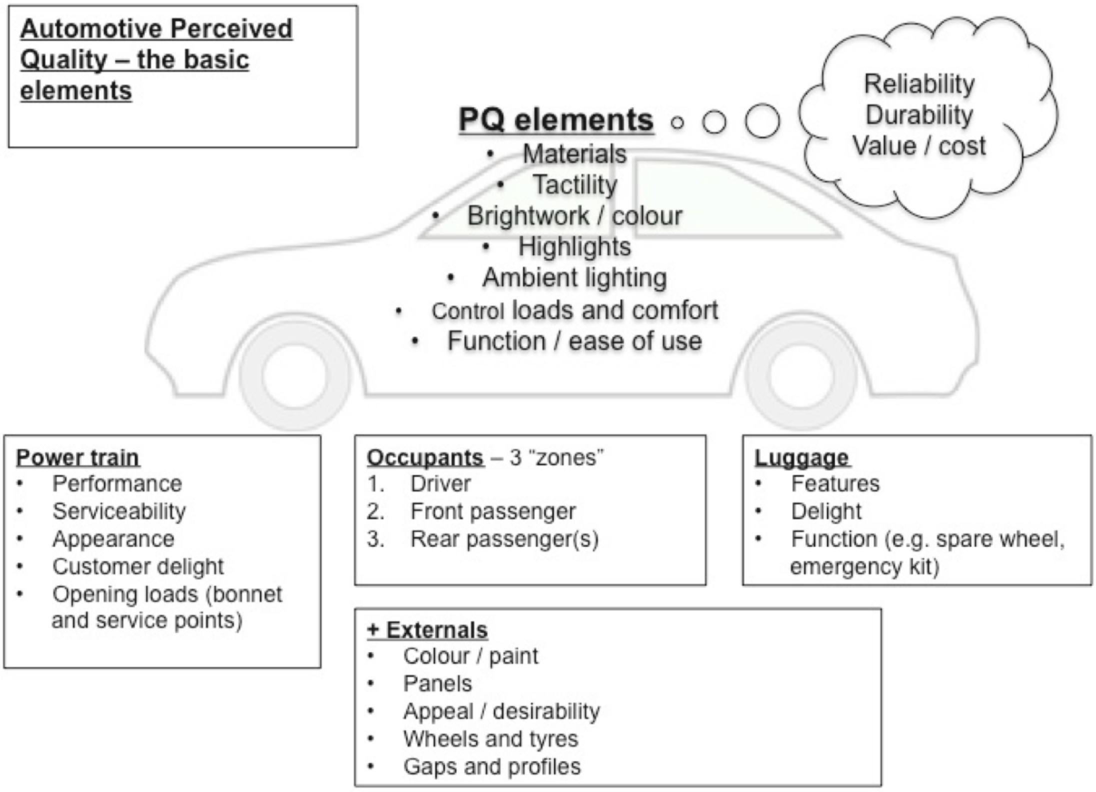


Fig. 2.5. PQ elements of a car (Pogson 2016).

2.2.1 The Manufacturer's PQ Audit.

As an example of the OEM view, one particular manufacturer will be used to illustrate the PQ factors. These could be termed attributes. The PQ attributes were originally created to analyse product quality for vehicle audits, where quality conformance checks were performed to assess how far away from perfect was a selected product taken at random from the production line. This is a very common form of product assessment across many manufacturing industries.

However, a regular PQ assessment scheme was created to give a view of what the customer really liked or disliked about products presented to them (Turley, Williams and Tennant 2006).

This could happen in a clinical setting, with models of new or proposed vehicles on show, or a line-up of that manufacturer's current range and sometimes including competitor vehicles. The PQ process (shown following) would start with a static review of the car, with the Facilitator or Auditor asking attendees to begin looking at specific elements of the car, always commencing with the exterior.

The PQ Process flow is shown in full in Appendix A2.3 and is summarised following in Fig. 2.6.

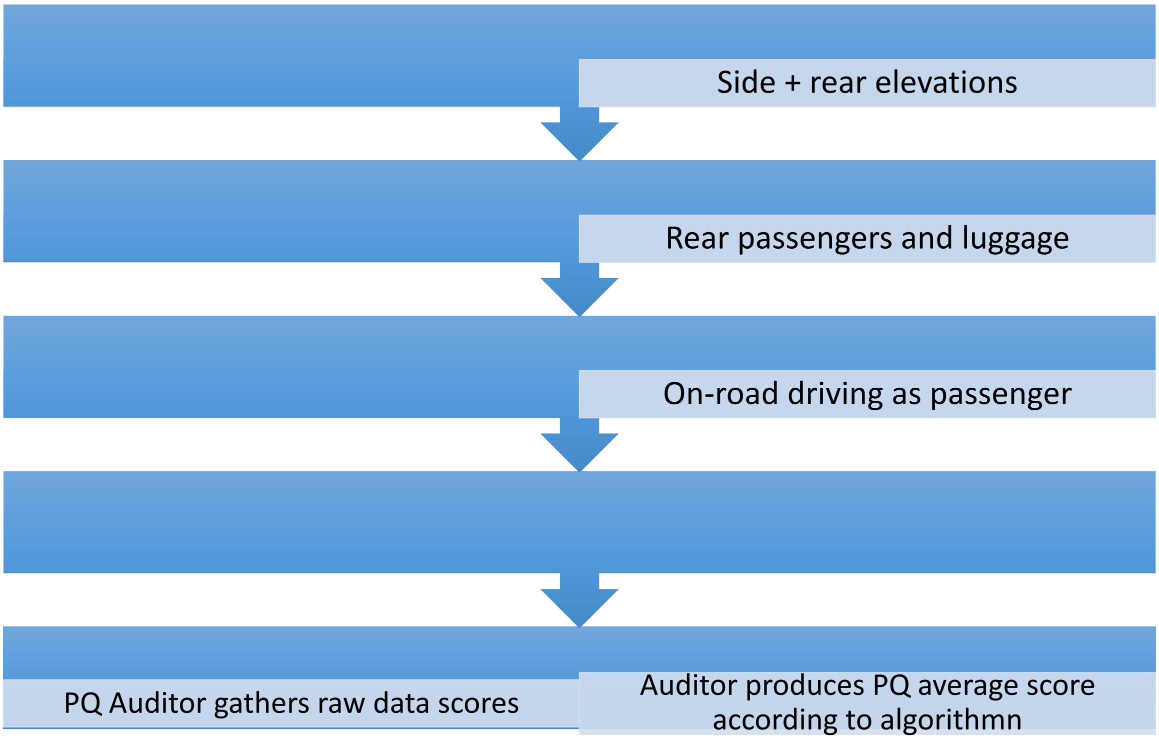


Fig. 2.6. PQ Summarised process – full day assessment per car. (By permission of the OEM, MG Rover Group Ltd. 2005).

The preceding process in Fig. 2.6 would be staged over one full day. The morning would commence with an introduction to the process flow by the Auditor, for those who were unfamiliar with the idea. Assessors are volunteers from within the Company and sometimes real customers or even prospects.

There is naturally a broad spread of experiences and expectations from those attending, bringing their own mental model or picture in their mind of the process and outcomes. Humans create models in their minds, which are simpler than the situation they are modelling. These are simulations of reality to help them along and make sense of the world by creating such mental models. We will return to mental models later in Chapter 3.

Those who have prior experience of such exercises are mixed with those who have none. The Auditor's skill is in providing clear guidance on process and output. The process generally takes three attendees and one Auditor a whole morning to cover exterior and interior static assessment, and then the afternoon would be spent driving and operating the car, from both a driver's position, as well as the passenger viewpoint. Static actions such as changing a wheel would be included. Any functions of the car were explored in static safety before venturing onto the road. On the drive, clear instructions to operate a feature or make a turn on the road were communicated by the Auditor if he or she were satisfied it was safe to do so.

One intriguing aspect of this process was a 'normalising' during the assessment as attendees ventured opinions and debated them between each other, either during the static or dynamic testing. Normalising is facilitated by the Auditor as an average of the rating scores given by each reviewer and in discussion with them. The conversation and debate are in itself quite interesting and illuminating as to what mental models people formed before or during the event. This is known as the 'customer murmur' when heard at vehicle launches or motor shows and is rarely captured formally, but is the customer or prospect venturing a view in what they see as a 'safe' environment. This is vital information for a manufacturer to understand and use in tools such as QFD (Quality Function Deployment), employed by many manufacturers (Sawyer 2007).

QFD takes customer 'wants' and turns them into Engineering 'hows' and is a powerful process which, when combined with other Quality tools such as Kano theory can provide a dynamic and insightful view of what the customer is thinking (Matzler and Hinterhuber 1998). It can shape the response of a manufacturer and give clues as to where to position the next product or feature.

2.2.2 Sample results from PQ and Quality Audits

The following two charts show PQ of various cars and the corresponding (if available) Quality Audit scores.

As previously described, PQ is *subjectively* rated by opinion of people in a group of three or four, plus an Auditor/Facilitator and is in two sections; static and dynamic (driving the cars over the same set route), often in the same location as the Audit scores are taken.

Audit scores are used by all manufacturers and are a rating of demerits, whereby problems of poor fit, finish, gap and flush are scored against a notion of perfection. Many of these aspects are measurable and give a more objective measure than current PQ studies. Figs. 2.7 and 2.8 following will show the comparison of PQ and Quality Audit scores.

The two scoring regimes are historically opposites with a good PQ score being high and a good product quality audit being low, as it is based on demerits, i.e. a demerit is recorded if a problem is found.

Both audit processes assess PQ and manufactured quality at one point in time and do not look at any degradation over time. This is usually assessed by running competitor vehicles in parallel with one’s own over the same tests.

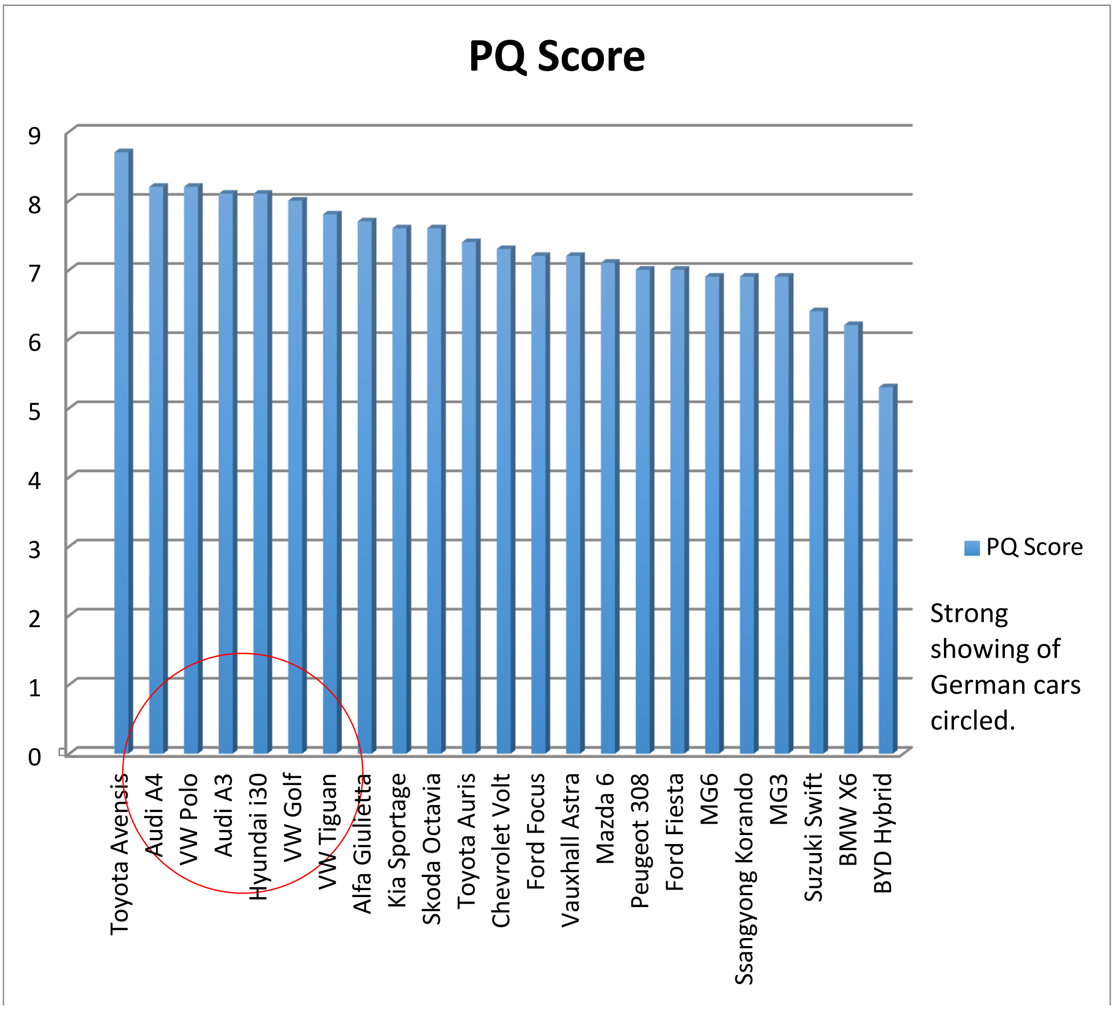


Fig. 2.7 PQ scores for a selection of cars

Fig. 2.7 above shows a series of subjective PQ scores for vehicles assessed by a Design Consultancy and shows a clear grouping of German-manufactured cars at the higher (better) end of the scale. Fig. 2.8 will show scores for the same cars as objective Audit measures.

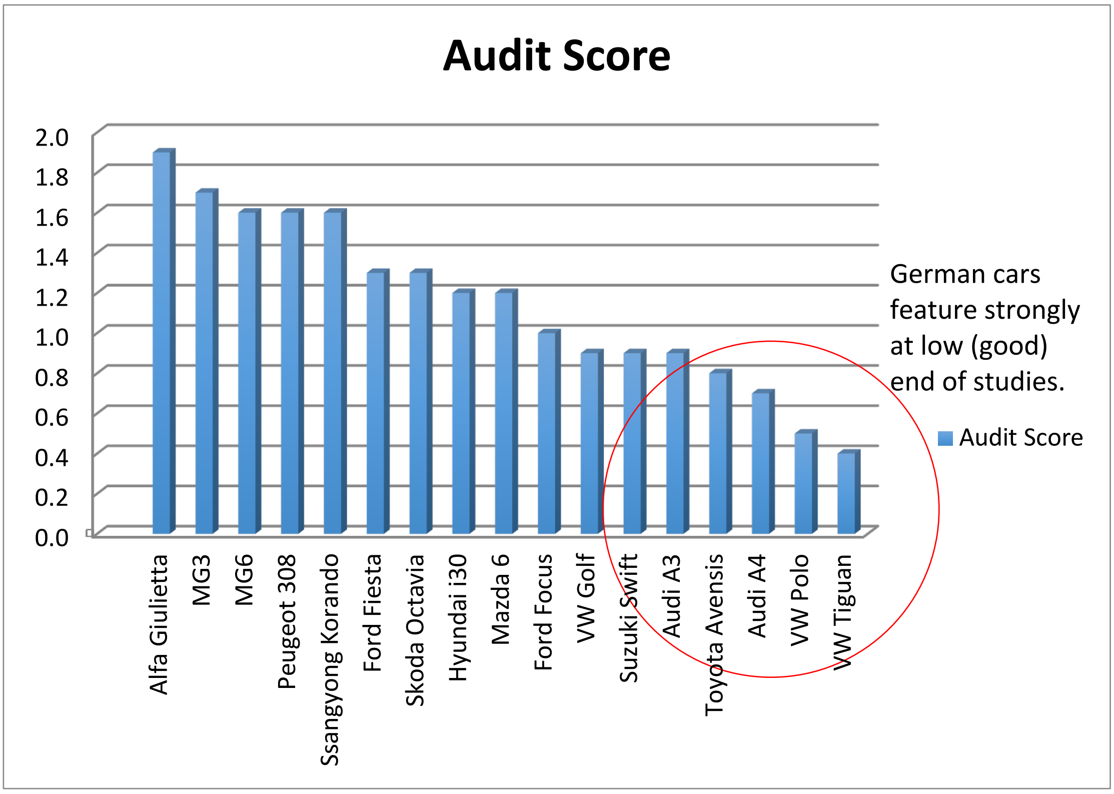


Fig. 2.8 Audit scores for the same cars

The vehicles circled in Fig. 2.8 are interesting as they cover the same cars as Fig. 2.7 but show the link between a low Audit score and a high PQ score. This data was gathered during 2012 to 2014 as vehicles became available.

The results shown in both Figs. 2.7 and 2.8 show inherited expectations held by individuals and organisations or OEMs from the sample cars. Both groups have the capacity to recognise differences in quality.

The same information is presented below in its base form as Table 2.3 for comparison.

Vehicle	**Company**	**Audit Score**	**PQ Score**	**Comment**
Alfa Giulietta	La meccanica delle emozioni	1.9	7.7	Worst Audit, but not worst PQ.
MG3		1.7	6.9	Poor audits and PQ
MG6		1.6	6.9	
Peugeot 308	PEUGEOT	1.6	7	
Ssangyong Korando		1.6	6.8	
Ford Fiesta	Ford Go Further	1.3	7	UK best seller.
Skoda Octavia	ŠKODA	1.3	7.6	A VAG subsidiary
Hyundai i30	HYUNDAI	1.2	8.1	
Mazda 6	mazda	1.2	7.1	
Ford Focus	Ford Go Further	1	7.2	
VW Golf	Volkswagen	0.9	8	
Suzuki Swift	SUZUKI	0.9	6.4	
Audi A3		0.9	8.1	
Toyota Avensis	TOYOTA	0.8	8.7	
Audi A4		0.7	8.2	
VW Polo	Volkswagen	0.5	8.2	VAG (Volkswagen Audi Group) – consistently good Audits and high PQ. Toyota also in this group.
VW Tiguan		0.4	7.8	

Table 2.3. PQ and product Audit data shown as a comparison table.

There is clearly more work to be done here, but there is a definite correlation between the subjective and objective sides, as shown by a detailed example of objective measuring now follows as described by Toyota.

2.2.3 Panel gaps – an example of automotive PQ detail

Panel gaps and profiles as shown above in the OEM Audit are also a key PQ attribute and will be discussed later in the attributes section of Chapter 4. One of the few published theses covering the subject of PQ made quite a point of gaps and profiles (Wagersten 2013). As an example of how important these issues are to a manufacturer (and as shown in Chapter 5for the OEM and Chapter 6, to customers), will be given below. First, a definition of the two will be presented.
A panel gap is very simply the measurable gap between one panel and the next, for example a wing and the leading edge of a door, as shown below in Fig. 2.9:

Fig. 2.9 Measuring panel gaps with digital gap gauge calliper (Lexus UK 2019).

It is also possible to measure gaps with a simple taper gauge, often referred to in the automotive industry as a ‘carrot’, for obvious reasons.
A regular pair of callipers can be used as well. The associated issue of gap taper (i.e. a change along the joint line) can also be assessed this way.

It has been proven that panel gap and taper or uneven gaps can be discerned by even untrained observers (Duraiswamy *et al*. 2018). Although these are measurable manufactured issues, they are key elements of the *perception* of quality.

Panel joint profile is also a key attribute or element of the perceived quality of a vehicle. It is the manufacturer's intention that most joints will be flat, i.e. running a straight edge or even a finger over the gap will show that both panels are at the same level and one is not proud of the other.

Table 2.4 below shows the results of an exercise to measure gaps from three different manufacturers across doors and fuel flaps. This exercise was conducted to see if there was an ideal gap to be used as a target in the development of a new vehicle.

Table 2.4. Panel gaps on Toyota Yaris, VW Polo and Vauxhall Corsa (Collected by the Author)
(See key to gaps following in Table 2.5.)

<table>
<tr><th colspan="10"><u>Body side gaps (in mm.)</u></th></tr>
<tr><th rowspan="2">Gap - see key</th><th colspan="3">Average gap of 10 cars</th><th colspan="3">Range across 10 cars</th><th colspan="3">Taper range of 10 cars</th></tr>
<tr><th>Yaris</th><th>Polo</th><th>Corsa</th><th>Yaris</th><th>Polo</th><th>Corsa</th><th>Yaris</th><th>Polo</th><th>Corsa</th></tr>
<tr><td>A</td><td>4.5</td><td>3.4</td><td>3.9</td><td>1.0</td><td>1.8</td><td>1.7</td><td rowspan="2">0 to 0.1</td><td rowspan="2">0 to 1.1</td><td rowspan="2">0.4 to 0.9</td></tr>
<tr><td>B</td><td>4.3</td><td>3.4</td><td>4.2</td><td>0.7</td><td>1.6</td><td>0.7</td></tr>
<tr><td>C</td><td>4.1</td><td>3.6</td><td>4.5</td><td>0.8</td><td>1.1</td><td>1.8</td><td>n.a.</td><td>n.a.</td><td>n.a.</td></tr>
<tr><td>D</td><td>3.7</td><td>4.3</td><td>4.8</td><td>1.4</td><td>1.8</td><td>2.2</td><td rowspan="2">0 to 0.9</td><td rowspan="2">0 to 1.8</td><td rowspan="2">0.1 to 1.3</td></tr>
<tr><td>E</td><td>3.6</td><td>3.7</td><td>4.9</td><td>1.5</td><td>1.6</td><td>2.3</td></tr>
<tr><td>F</td><td>4.1</td><td>3.6</td><td>4.4</td><td>1.8</td><td>1.2</td><td>2.0</td><td rowspan="2">0 to 2.6</td><td rowspan="2">0.2 to 2</td><td rowspan="2">0.1 to 0.9</td></tr>
<tr><td>G</td><td>4.2</td><td>3.4</td><td>4.6</td><td>3.0</td><td>1.7</td><td>1.3</td></tr>
<tr><td>H</td><td>3.9</td><td>3.4</td><td>4.2</td><td>1.6</td><td>2.1</td><td>0.7</td><td>n.a.</td><td>n.a.</td><td>n.a.</td></tr>
</table>

Table 2.5. Panel gaps key

Gap from table 1.7	Location on vehicle (either side)
A & B	Front edge of front door to front wing
C	Base of front door to sill
D & E	Front edge of rear door to rear of front door
F & G	Rear edge of rear door to rear wing
H	Fuel filler flap to body side

The data from the table shows that there is a drive by these manufacturers to achieve a minimum gap that still allows door opening and is able to be reproduced in the pressing and assembly of the car. Such a minimum was the figure that was sought through this exercise and was an indication of how achievable it could be and repeatable it could be made in reality. 4mm was the nominal gap suggested from analysis of this data that was accepted by the Design Team at the Consultancy for which it was performed.

2.2.4 Automotive manufacturers' presentation of PQ via their websites

Following in Table 2.6 is shown a selection of Global OEMs, including some UK niche-manufacturers and a search of their websites for any mention of PQ. The results are quite disappointing. There is clearly much work to be done investigating PQ and presenting it to the customer in an accessible way. Of all the sites viewed below, only Lexus was particularly and effusively informative about craftsmanship and PQ. Renault and Peugeot had some mentions of PQ. See Appendix A2.4 for the web-site addresses.

Table 2.6. A sample of automotive manufacturers' websites and a search for PQ thereon.

Marque or OEM		**Result of "perceived quality"search**
Audi		There are "0" results for: "perceived quality"
Bentley Motors		No search facility, but access to their Recalls!
BMW		There are "0" results for: "perceived quality"
Citroen		No search facility
Chrysler		No search facility (do not sell in UK in 2019)
Fiat		There are "0" results for: "perceived quality"
Ford		There are "0" results for: "perceived quality"
Geely		There are "0" results for: "perceived quality"
Honda		No search facility
Lamborghini		There are "0" results for: "perceived quality"
Lexus		Good section with videos on Craftsmanship, testing, development and their 'Takumi' craftsmen. Design, performance and technology.
Morgan Motors		There are "0" results for: "perceived quality"
Nissan		Two articles on "perceived quality".
Peugeot		Attractiveness, Lighting, Sound spatialisation & Olfactory senses
Renault		One mention on Ecolab car project.
Rolls Royce		There are "0" results for: "perceived quality"
Triumph Motorcycles		There are "0" results for: "perceived quality"

Of all the entries in Table 2.6, Lexus is head and shoulders above all others, having videos and images showing their "*Takumi*" craftsmen and women at work creating PQ in Lexus cars (Lexus UK 2019). This only a sample of world-wide marques, but does Lexus give an indication of the future for PQ promotion?

2.2.5 Credited automotive advertising slogans with PQ inferences

The findings above in Table 2.6 are in direct contradiction to what is portrayed by automotive Marketing Departments in their advertising slogans, where at least some elements of PQ - attributes - are mentioned. These elements will be discussed in the following chapters.

This is shown by the following collection of marketing slogans, collated and written into prose. The plain bold text are those slogans used by the manufacturer indicated, with link words added to make sentences in italics.

> *It starts with* **a passion for the road**, (Mazda), **engineered to move the human spirit** (Mercedes Benz), *but* **don't dream it; drive it** (Jaguar). **Enjoy the ride***and***shift expectations** (Nissan) *of* **what a luxury car should be** (Lincoln). *However,* **beauty is not enough** (Alfa Romeo) *and* **the power to surprise** (Kia) *is* **fuel for the soul**, *so***we are driving excitement** (Pontiac), *into* **the drive of your life** (Peugeot).
>
> *The* **future of the automobile** (M-B) *is* **designed for living***and***built to last** (Ford), *so* **dream up** (Buick). **Grace space and pace** (Jaguar) *are* **in a class of its own** (Rover) *with* **technology you can enjoy** (Honda) *in* **the ultimate driving machine** (BMW), **driven by passion** (Fiat). **Have fun out there** (Jeep) **for the love of the car** (VW), *in* **precision crafted performance** (Acura), *where* **quality is Job one** (Ford). **Small wonder** (VW) *that* **the relentless pursuit of perfection** (Lexus) *results in* **the art of performance** (Jaguar). **Think, feel, drive** (Subaru) *and* **Go Beyond** (LR).'

The preceding advertising tag-lines are extracted from research on marketing (Advergize 2018).

The plain text are those slogans used by the manufacturer indicated. Some may be familiar from television, on-line or in-print advertising and are restricted to those used in North America and Western Europe, as these were easily obtainable and may be familiar to an English-speaking reader. These slogans were selected on the basis that they:

- used language found in the study of Engineers in Chapter 4 or the user survey in Chapter 6
- employed words such as ‘quality’, ‘craftsmanship’ or ‘luxury’, i.e. words at the core of this research.

These slogans imply that the manufacturer wishes customers to associate PQ with their product by the use of such emotive language, which will be discussed in Chapter 6. One of these slogans, BMW’s “Ultimate Driving Machine” will be examined in more detail in this Chapter. We shall now examine what PQ means to an OEM in the next section.

2.3 Defining automotive attributes

Attributes will occur repeatedly throughout this thesis; in the three surveys herein presented, the Engineers work to pre-defined attributes laid down by Marketing or Product Planning departments. An attribute can be a feature, characteristic or even as shown in the following example, a manufacturer’s identity. Appendix A5.1 shows 32 papers defining attributes. The OEM’s attributes will be expanded upon below and are the very things that a customer looks for - often unconsciously. Attributes can be themselves the very definition of a manufacturer. They can be the OEM’s internal view of what they see as important – as mentioned before, their Brand identity. An example of such identity via attributes is discussed below for BMW.

Automotive manufacturers usually see attributes as an inherent property of their vehicles, which contributes to their desirability (Stylidis, K., Wickman, C., and Söderberg, R. 2015a). This thesis defines attributes as qualities or aspects of a vehicle that the Engineer will design to, and the customer will recognise, if not articulate, when assessing the product’s PQ.

Attributes therefore take on their own form and characteristic – a commodity that can be advertised and promoted, sometimes becoming embedded within the product description or even marque advertising strap-lines. For example, the use of the phrase “the ultimate driving machine” by BMW, see Fig. 2.10. We have seen this use in the slogans in section 2.2.5. Chapter 5 will consider the OEM and attributes in more detail.

OEMs do present their PQ attributes in marketing literature but tend to focus upon them as a simple feature, hoping that the customer will make the link to PQ from that feature being present. For example, some motorcycle manufacturers, such as BMW, CCM, Triumph, Indian and Harley Davidson have recently made remote lock/unlock a feature, as fitted to cars for many years. In the case of bikes with panniers, these are included in the central locking facility. The hope is that this feature brings a motorcycle up to car standards of convenience and feature content, with a corresponding ‘wow’ factor to aid PQ recognition.

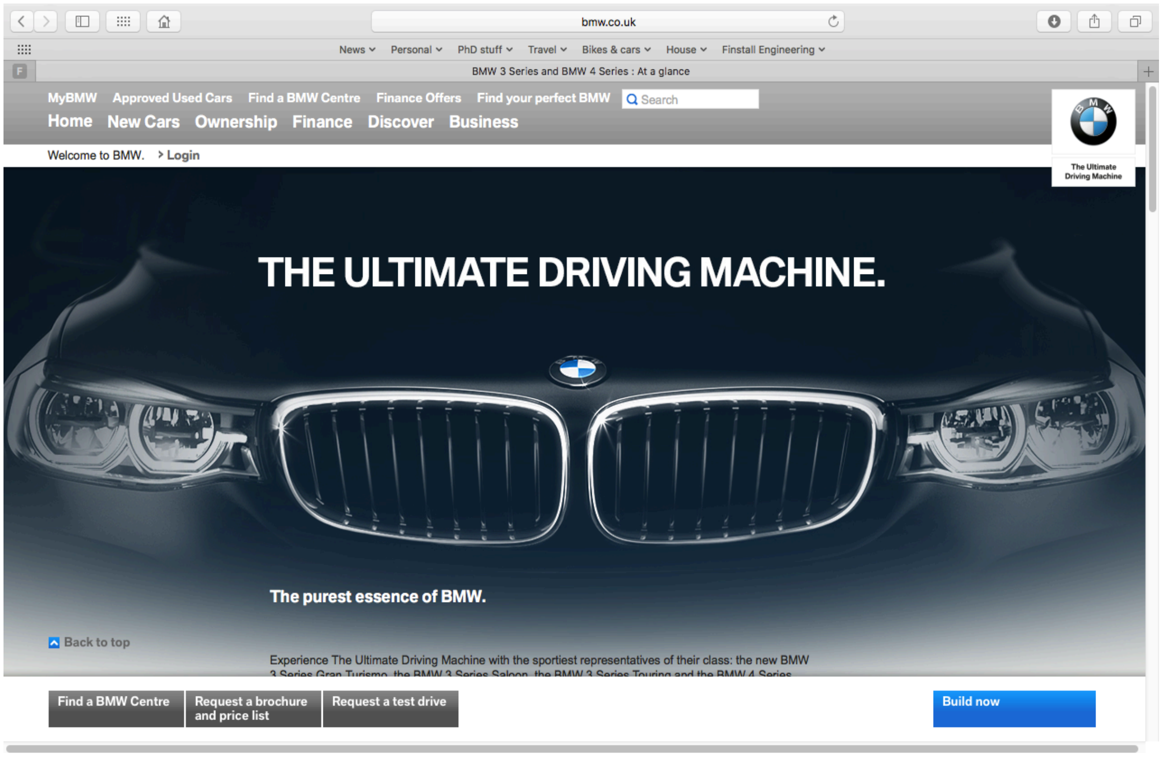


Fig. 2.10. The use of attributes to generate an advertising slogan (BMW UK 2019)

Therefore, if the example of BMW in Fig.2.10is considered, it can be assumed that its prime attribute is its drivability, but what does that mean?

Drivability could mean different things to different people and could well include such topics as noise (or the absence of it), steering feel and feedback, operating loads for clutch, steering, gear-change, throttle and ancillary controls. It could mean the primary ride quality, (generated by the reaction of the car to the big, visible imperfections in the road surface) and the secondary ride, or higher frequency/lower amplitude (that taken care of by bushes and dampers).

The meaning could also be such performance topics as acceleration, measured in speed increase over time, but also with a perception of acceleration being emphasised by a throaty exhaust or also quite the opposite, if one were in the quiet, serene ambience of a Rolls Royce. Attributes will be discussed further and used as the basis for the survey of an OEM in Chapter 5, but we must first look more specifically at automotive PQ.

2.4 PQ at JLR

The following appeared in a 2011 job advert in 'Quality Journal' and gives a public insight into PQ at a major OEM, Jaguar Land Rover.

> *"Our customers expect our premium vehicles to be thrilling on every level. As a pivotal member of the Perceived Quality department, you'll play a lead role in defining and measuring customer requirements for emotional and sensory interaction connection with a wide range of Jaguar Land Rover products".*
>
> *"You'll be instrumental in setting standards and driving design and engineering solutions. Naturally, the leadership of Perceived Quality processes will call for liaison and close collaboration with a diverse range of functions – from Design, Engineering and Company Quality to New Model Programmes, Advanced Manufacturing and Plant.*
>
> *With excellent communication, presentation and relationship building skills, you'll champion Perceived Quality and ensure excellent results through an integrated, cross-functional approach,"* (JLR 2011).

Further details and the original advertisement are to be found in Appendix A2.5. A key word used in the advert is “thrilling”, to describe how the product should appeal, and a need to define and measure PQ customer requirements is stated (see later in this thesis, Chapter 6). PQ and standard setting are also mentioned, as is a liaison role with other departments such as Design, Engineering and Plant. PQ is a subject which crosses all functions and evidence will be presented through the thesis to back up this assertion.

2.4.1 JLR PQ Definition

The Company’s view of PQ is also presented in the job advert and suggests that:

> *“PQ is the perception of quality by a customer, based on sensory interaction and emotional connection.*
> *The role of PQ is to ensure that the product should be desirable, well crafted, with premium materials, jewel-like detailed features and relaxing ambience,”* (JLR 2011).

Does the answer to “What is PQ?” lie behind this OEM’s door in Fig. 2.11? (Upon investigation the room was empty).

Fig. 2.11 A door to PQ?A "Perceived Quality Room” – found on an OEM visit (Author 2018)

2.5 When PQ is absent

Despite manufacturers’ best efforts and intentions, PQ can be absent from the finished product, or any good PQ is masked by serious faults. An illustration of this is in his book on (in his opinion) pitiable cars, where Porter (2004: 125) puts the VW Beetle, (so popular that its production run lasted nearly 6 decades and even featured in its own films) as the worst of the worst. The VW even eclipsed the Austin Allegro and Lada Riva. It has to be the aim of any OEM not to feature in such a tome.

Other, more academic sources will be critiqued in the next chapter, the meta-data review, but we will now consider an OEM who is serious about improving PQ. The aim of all OEMs is to avoid the escape of PQ – i.e. where the original intent to include PQ leaks out or is lost early on in a vehicle programme. Fig. 2.12 following shows where some of these escape points lie.

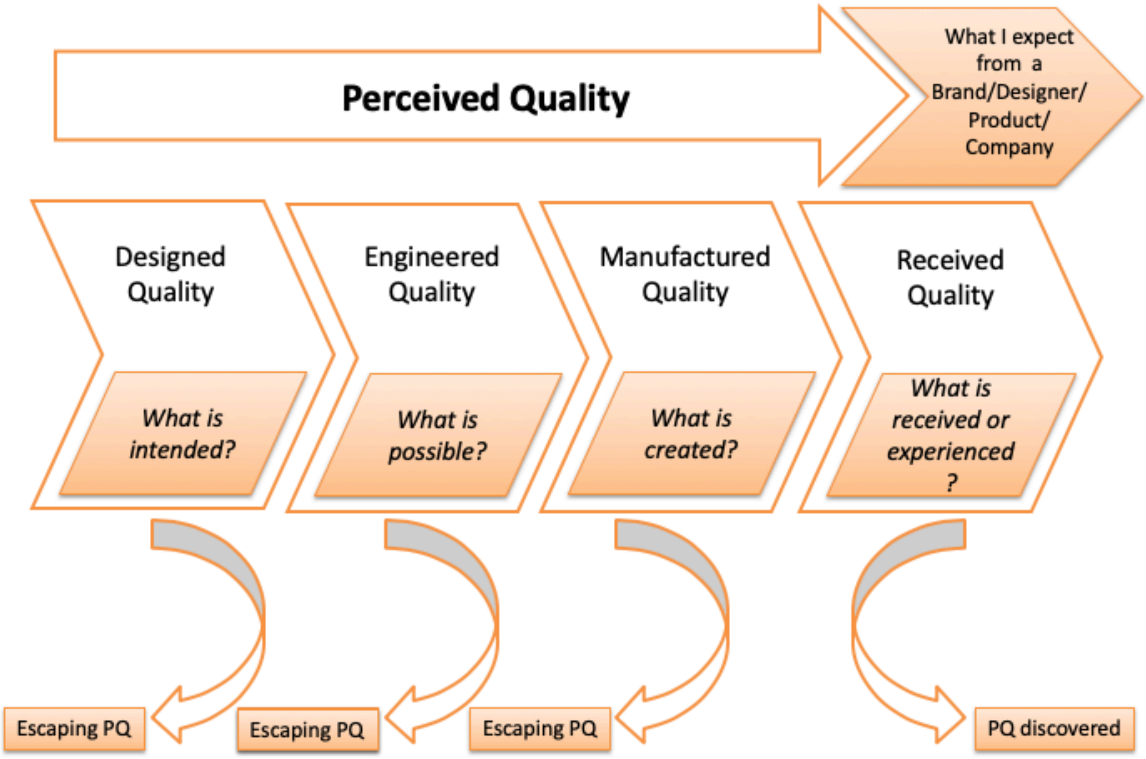


Fig. 2.12. PQ influence, escape and delivery points (Pogson 2016)

Fig. 2.12 shows three of the possible escape points where intended PQ is lost due to other priorities of the project taking precedence, for example the Engineer not being listened to or barriers such as budgetary issues preventing PQ input being realised.

2.6 PQ and the relationship to car sales

A question voiced by the instigator of this research was "Is there any connection between improving PQ and increasing vehicle sales?"

The Quality Manager expressing this query believed there was and should be but did not have the data to back up any response. A consideration of some data from the marketplace shows there to be a link between the two.

Skoda already cited at the start of this research and Dacia are here compared to Ford in terms of their quality and sales figures. Ford has been active selling cars in Europe since the dawn of the automotive era, with Skoda also commencing sales in the late 19th century and Dacia from its base in Romania in 1966.

Skoda, although having made cars since the early years of the automobile, was a relatively low-volume manufacturer. It sold two budget models in 1991, such as the Estelle and its vehicles were once characterised by poor quality, cheap prices and were the brunt of many comedians' jokes, until after it became part of the VW Group in 2000 (Braithwaite-Smith 2015).

Skoda now shares components with other vehicles in VAG (Volkswagen Aktiengesellschaft, or Volkswagen Group), such as VW cars, Audi, Seat, benefitting from such volumes and consequential development. Cars such as the Citigo, Fabia, Kodiaq, Octavia, Rapid, Superb and Yeti are now well-regarded quality cars (Moody 2016). Reassurance for customers is given through brand association and shared components within the VW Group of companies.

Dacia, taking its name from the northern Danube area of Romania, made the same pick-up truck for over 30 years, before the country joined the EU and in 2006 it became unsalable in the new, expanded market.

Dacia has, however gone on to grow as a brand relying upon cheap, reliable cars driving sales.

A technical agreement with Renault of France has been in place for decades and it became a subsidiary in 1999, so has been expanded to produce vehicles of a more modern appearance in a low-wage area. The new cars - Dokker, Duster, Logan, Lodgy and Sandero have been a sales success, as shown in the following chart Fig. 2.13 and also are viewed as much improved from the PQ viewpoint (Adams 2019).

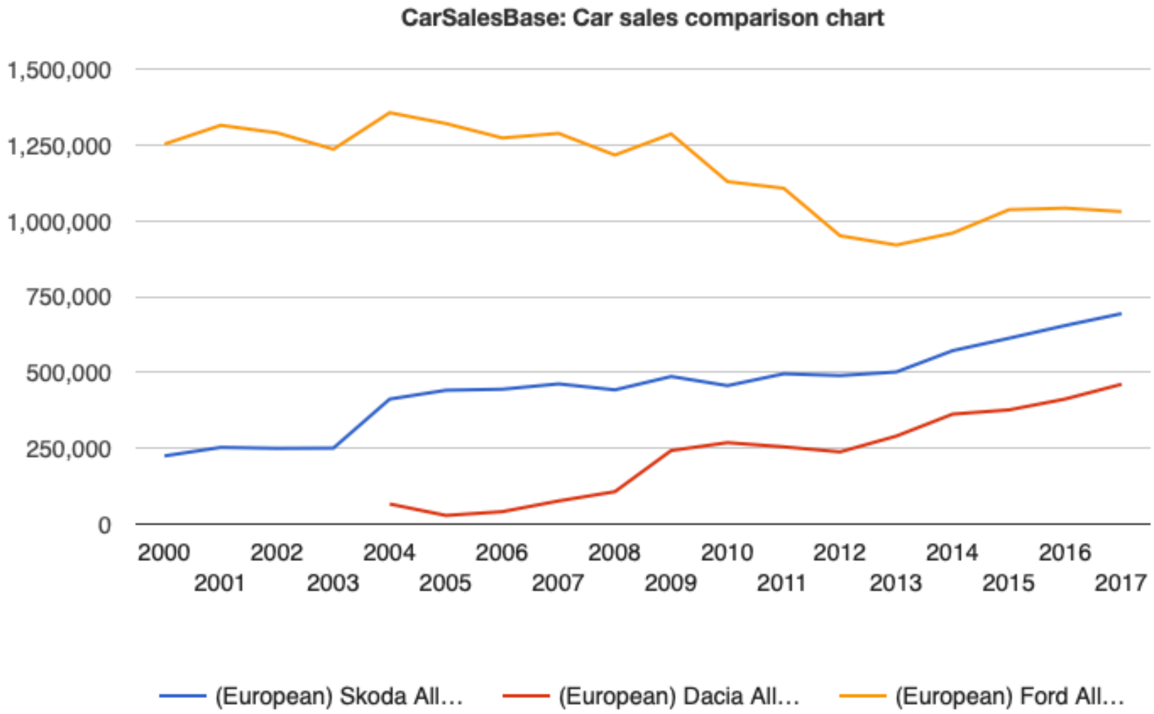


Fig. 2.13. European sales of Ford (falling), Skoda and Dacia rising (Car Sales 2019).

It would be expected that there is a relationship between PQ and increased sales and the above graph Fig. 2.13 as well as independent assessments of vehicle quality, which would give some support to the statement.

The next section will consider how these relationships can be explained and presented. A representation of the interdependencies of PQ and purchasing is shown in Fig. 2.14 following.

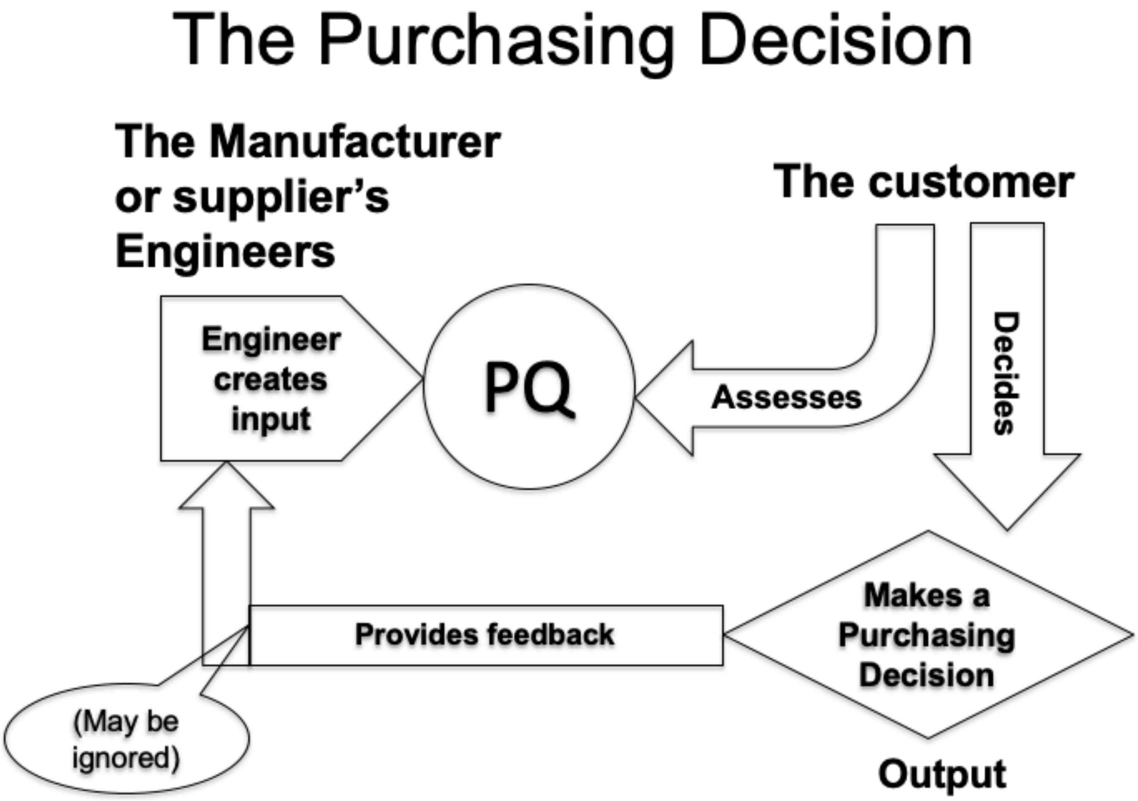


Fig. 2.14. The inter-relationships of PQ and purchasing a vehicle (Pogson 2016)

Fig. 2.14 above shows the relationship of PQ and the purchasing decision developed from experience by the Author. (Purchase here could mean outright ownership, Hire Purchase, PCP or other way of being the user of a vehicle). It is possible that once the Engineer creates the PQ under direction from an employer such as a supplier or OEM, that the customer then assesses the PQ, makes a decision influenced by this and this will produce feedback (if it can be recorded), which may be ignored by the OEM. The cycle then repeats.

2.7 Brand and PQ

It was originally envisioned in the thesis to create a stand-alone chapter to cover Brand and its relationship with PQ. Well over 8% of the meta-data studied as background to this research covered brand, in many instances intertwining brand and other key aspects of the research, such as design and emotion (Bird 2014,Afsar 2014). Many markets are extremely brand-conscious, with even multiple brands such as ABB (Audi, Mercedes Benz and BMW) being seen almost as one choice (Bhuian 1997). UK customers make up a lion's share of BMW output (9.8% of output in 2017), buying as much product as Italy, Japan and France combined (Statista 2018).

Early on in the research for this thesis, it was recognised that brand or brand equity (that which a Company invests into its brand strength) was a very powerful aspect of PQ, so a visit was made to Triumph Motorcycles UK which, in the two-wheeled transport world is a strong brand. It also arguably sells motorcycles because the PQ is seen to be high. This author has owned two new and one second-hand Triumph and strong PQ was certainly a driving issue in the purchase decision. An interview with a senior Triumph PR employee is included in Appendix A2.6, which covered questions on Triumph and its view of PQ.

However, Brand is such a massive subject on its own that although it has a proven, strong relationship with PQ, this fact will be acknowledged and considered outside the scope of this thesis (Dursun *et al*. 2011).

2.8 PQ, Customer Clinics and the Research Hypotheses

All manufacturers protect and nurture their brand image and although brand is considered outside the scope of this work, the opportunity presented itself to attend a Customer Clinic during the course of the research. This opening was seized upon, as it was a rare chance for an Engineer to join such an event and became a pilot study from which the hypotheses could be developed.

Customer clinics are used by manufacturers to gain insight into the voice of the customer, to which we will return in section 5.1.4.

The process for organising such an event, which can be held at a remote site to preserve manufacturer identity (or this can be inferred or even made plain) follows.

2.8.1 Clinic organisation - A generic model of how a clinic runs

Such clinics use a common methodology as an industry standard, which is maintained as much by the specialist facilitating company as the manufacturers. Both parties are keen to harvest the customer narrative by the spoken word and the physical reaction as shown in the flow process in Fig. 2.15. It is in both parties' interests to keep attendees happy, as they would not wish for negative feedback, which could taint the patronage of further clinics.

Fig. 2.15 Customer clinic flow process

1. New model is planned, OEM via Sales and Marketing wish to gauge possible reaction early in the design process. Clinic is decided upon as an investigative tool.

2. S&M engage a specialist screening company who search out potential customers against a profile created by S&M. The profile could include previous and current cars, aspirational vehicles and may be targeted at age groups, social/income levels, etc.

3. Location agreed upon with a suitable large viewing room and is provided with properties - full-size models or mock-ups of current product, intended product and possibly even competitor vehicle(s).

4. The room furnished with tables, refreshments and is wired for audio-visual relay back to a remote viewing room. Attendees are aware of this and give their consent ahead of the event and again upon arrival.

5. Discretion, attendee's comfort, safety and a relaxed atmosphere are clear goals.

6. The remote viewing room is populated with multiple screens and head-sets so viewers from S&M and other interested functions can observe without intruding upon the event.

7. Specialist facilitators from the screening company engage the groups of invitees and initially generate a relaxed atmosphere with general questions and conversation, then move on to stimulate dialogue about the process and cars.

8. Once they feel the group are ready, the formal process begins, and more directed questions are given the group for consideration regarding the properties in the room.

9. After this grounding, the group is invited to stand and view each model in turn, with very specific questions asked to gauge reaction. This is an excellent demonstration of what we will discuss later in Chapter 6 on Design and Emotion.

10. Qualitative data is duly extracted, as is the *way* in which it is given. This is a good demonstration of the direct voice of the customer being presented.

11. As the whole event is recorded, this gives time later for lengthy analysis. The customer narrative is therefore pored over and even body language can be re-assessed with the video recordings.

12. The facilitators continue until the questions set by the manufacturer have been exhausted or the specification for the clinic has been met.

13. Throughout, the attendees safety, comfort and level of interest are closely monitored to ensure everyone is satisfied, as their welfare is paramount.

As this researcher’s presence at the clinic was hard-won and only sanctioned by grace and favour, but mostly because the information gathered is so sensitive, any data collected thereby could not be presented here. The results are regarded as highly confidential, even the date and location would be regarded as sensitive data. For GDPR reasons attendee details would be impossible to reveal and any model information is commercially sensitive, so it is hoped that the process description already described will give an impression of the data collection possibilities, but that none of this can be revealed herein. What can be shared is examples of the questions asked during the process, but the responses must remain confidential. The vehicles in the room were just given a letter designation, such as X, P and J. P, for instance was a new, unreleased model.

Sample clinic questions asked by facilitators:

1. "What direction do you think manufacturer Z is moving in, towards what destination?
2. What cars do you drive now?
3. What does the customer get from these?
4. What words would you use to describe these cars?
5. If you had to swap the car, what other car would interest you most?
6. *(Facilitator summarises responses)* Have I missed anything?
7. Comparing models P and J, what is your preference?
8. Where is P's living area - urban or town?
9. When do you expect the car to come out?
10. If these cars (J and P) were from the same (*manufacturer's*) 'family', what would that be?
11. If P is not available, would all of you rush to buy J?
12. Of cars L and M, what is preferred?
13. Why are we struggling with a decision?
14. Is this not what you expect of the new................? *(Model name redacted)*.
15. Here is the urban .... - does it work?

16. If I gave you M for a week, would you find it useful? What are the positives?
17. Do you see a market share for any of these cars?
18. Please look specifically at model R. Will it make its mark and stand out?
19. Car S - what is it?
20. What is the car for?
21. Please stand by your favourite car".

This concluded the session. It can be seen from the questions that aesthetics were driving much of the conversations. Only two cars were opened to allow a view of the interiors. Some exhibits were exterior styling models with no interior. There was some confirmatory analysis in the questions to see if the planned new models were going to be well received, at least by this group.
Some of these questions mirrored those used in the Chapter 6 survey, vindicating the choice made to ask them in the study.

It was important for a PQ researcher to experience one of these events, as it was hoped that the information would be of use to the thesis, but as so much of that gathered would have to be redacted, the surveys which have been carried out in Chapters 4, 5 and 6 are the more valuable. The experience did however provide a point from which the hypotheses could be developed, so although it was disappointing not to be able to use the harvested data, this development opportunity was taken and so the hypotheses are explained at the head of each study chapter.

2.9 Concluding remarks and an OEM definition for PQ

This Author’s view is that the most succinct definition yet given was voiced by a Jaguar Land Rover Manager at an internal 2016 JLR Technical Specialist’s Conference.

It is given here by permission of the speaker, Steve Harris, a PQ Specialist and also by the Board Director for JLR Quality. It is very simply, one word:

AUTHENTICITY

(Harris 2016)

(Upon further questioning, Mr. Harris acknowledged that although he stood by it, this was not his own definition, but sadly could not recall the source of the quote.)

The more one considers this word, the more sense it makes to those involved in creating vehicles with PQ. However, one word is not a thesis, so further analysis will be made to discuss alternatives. One recent quote, by a young Apprentice claims that “We can see three dimensions: it’s not just solely product based, it’s not just getting it right first time, it’s addressing the needs and requirements of clients and stakeholders” (Tennant 2017).

The full extent of the meta-data and critical reading examined for this thesis will be examined next in Chapter 3, where it will be shown that a simple tool for categorising the research will organise and present that which currently exists. Although developed for the Consultancy that originally sponsored the research, use of the tool has been continued as it represented a useful manner to log meta-data and extract some statistics from the available material. The two principal methodologies for this thesis will also be explained in more detail; ISM and Mental Models.

Chapter 3 – Studies of Perceived Quality: a meta analytical review

3.0 Introduction

We have seen in Chapters 1 and 2 that whereas automotive PQ is a subject of much interest to OEMs it can be viewed by them as confidential and often not even shown on their web-sites, as shown in the previous chapter, 2.2.4 in Table 2.5. So, we shall now investigate for previous relevant research in the public domain. Mention has been made of two centres of research in Sweden and Germany, so PQ is an active area for research. This Chapter will show that over 330 items of interest have been examined; some useful, others not so. The need for understanding them and a method of logging the material and critically assessing the same, summarising their useful content will be described. This will be presented by way of examples at the end of the Chapter.

This Review shows the development of a methodology and tools for managing extensive research on the subject of PQ. The main driver for the review was to serve the needs of the PhD thesis. The methodology also responded to demands from the original sponsoring Company for a repository of research that would be easily accessible to employees and searchable by them. Two years into the 5-year PhD timetable, the research took a different viewpoint through another Company, so a revised commercial and academic purpose was developed. This significantly improved the quality of the review and generated some interesting statistical analysis opportunities. It sharpened the thesis focus and validated its direction.

3.1 Quality and Perceived Quality

Elsewhere in this thesis (Chapter 2.1) the difference between manufactured product quality and PQ is described. PQ is not a subject where there have been many 'breakthroughs' in research, although it is a fairly new area of debate (van Laack 2014).

It is also a developing area, with a cluster of researchers in Sweden at Chalmers University/Volvo Cars (Wagerston, Wickman and Soderberg 2009, Wickman and Soderberg 2010). Web-sites devoted to or mentioning PQ are few (Roffey 2012, BlueThink 2019), while some of the closest and best research found by this writer has grown out of Delft University and the 'Design and Emotion' group (Hekkert 2017).

For PQ, there are few specific conferences, yet a great deal of commercial interest and OEM's accept its importance - but little formal research at academic level. There are as many ideas of what constitutes good PQ as there are writers on the subject (van Laack 2014). Straight product or manufactured quality is represented well in the research and written domain, such as trade and institution journals, but PQ much less so.

Therefore, what was required was for a systematic review of the literature in relation to the analysis of automotive PQ, its definition and how it can be measured in particular. As the original driver for this research topic was rooted in an engineering consultancy looking for PQ information, then it would serve the latter well to have a repository of accessible background research on PQ identified and assessed. This was an early aim for the research and a description of how this was achieved follows, but first a quick consideration of what exists via a key-word search is described.

A simple key-word search on three websites shows some interesting results, as in the amount of hits or articles, as shown following in Fig.3.1. (Scopus, Chartered Quality Institute and Google Scholar, January 2019).

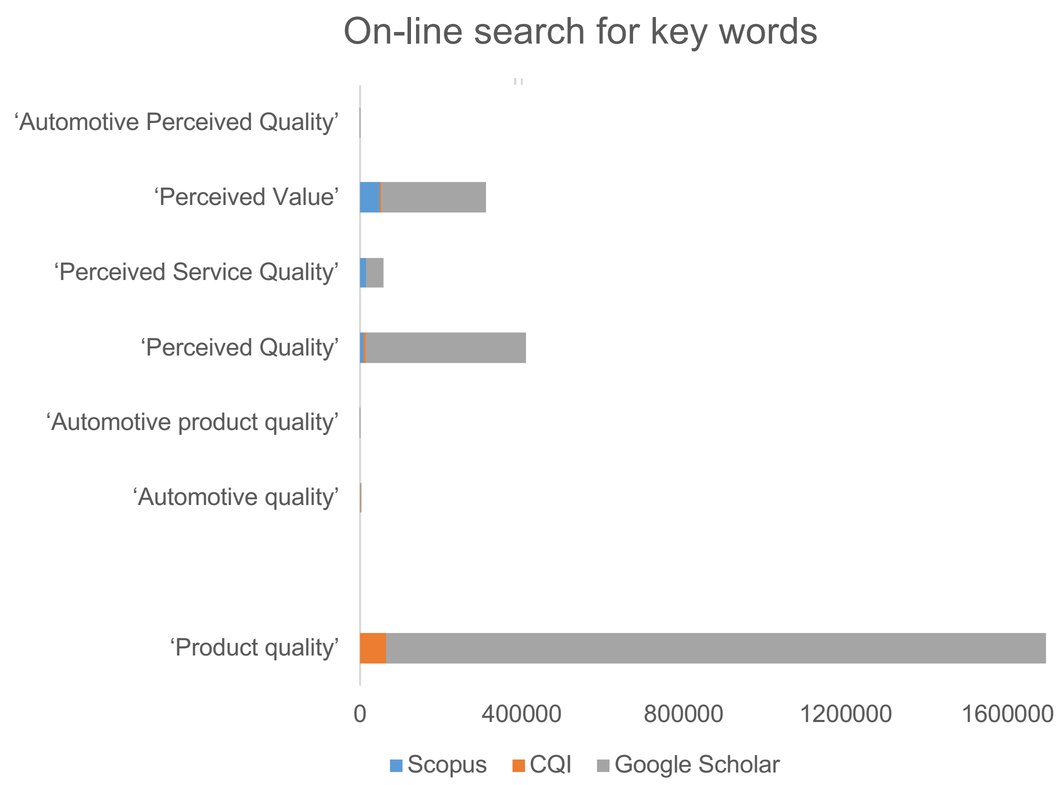


Fig. 3.1. On-line search for key words listed

Subjectively, from this very simple analysis that PQ is not well represented in research terms. Perceived Value is almost as well shown as PQ and straight product quality is particularly well covered. The automotive PQ world seems however, to have few entries.

PQ may be viewed in a more unique way however, as it is not necessarily bound to the confines of academic research or understanding. Indeed, we all can have an opinion of something that may be alluded to possess a value that may be defined as PQ.

Examples of current commercial 'measures' fall short of being complete due to their mainly quantitative nature; opinions require more than a simple metric to analyse and represent them (ALG TrueCar 2012). So, PQ is largely unresolved as a measurable state, being usually shown on a numeric scale such as 1 to ten, or poor to excellent.

One well-established method from 1997 looked at the “Development of a Multi-dimensional Measure of Perceived Product Quality” (Stone-Romero, Stone and Grewal 1997). The authors concluded that very little evidence existed in the literature they studied of more than a single PQ dimension.

However, the plan with this new research was to consider what has already been written, evaluate it, build upon it and create a more useful PQ measure. This Literature Review has considered over 330 books, papers and conference proceedings and a statistical analysis of these is given later. The review commenced with a fairly simple structure, but this has developed into a useful research tool capable of providing analysis.

The creator of PQ (as discussed in Chapter 4), being the Engineer, is not well represented in the PQ literature, either. This is shown by a search on the word ‘Engineer’ in some of the reviewed documents as below in Table 3.1 following. The sources are shown in the thesis Bibliography. The table represents how few times the word Engineer appears in a search of the 330-plus items read as background material for the thesis.

Table 3.1. Word-search for “Engineer” in literature, with sources listed in the Bibliography (Crit? = Critiqued = C).

Ref. no.	Crit ?	Brief Title	Author/date	Source journal
9	C	New metrology culture improving Chrysler quality (Auto).	Morey, B., 2013	Manufacturing Engineering, Vol. 151, Iss. 3
40		Introduction to quality engineering.	Taguchi, 1986	Book, p.73
44		Improvement of process.	Shingo, 1981	Book, p.33
48	C	PQ Perspective in Design Management.	Kataoka, A, 2004	Automotive Eng’g Vol. 25, Iss.1 p.381
68	C	Detecting subtle cosmetic defects in automotive skin panels (Auto).	Hazra, S.; Williams, D.; Roy, R.; Aylmore, R., 2008	Proceedings of IMechE. Vol. 222, Iss. C, p.2203.
71	C	A Framework for Empathy in Design: Stepping into and Out of the User's Life.	Kouprie, M. and Visser, F. (2009)	Journal of Eng’g Design Vol. 20, Iss. 5, p.437
74		Non-rigid behaviour prediction based on styling data for evaluation of perceived quality (Auto).	Wagerston *et al.* 2009	ASME (2009) International Mechanical Engineering Congress & Exposition
76		A framework for non-nominal visualisation and perceived quality evaluation (Auto).	Wagerston *et al.* 2011	ASME 2011 International Design Engineering Technical Conferences
92	C	Towards non-FEA-based deformation methods (Auto).	Wagerston *et al.* 2013	Journal of Engineering Design Vol 24, Iss. 9 p.623
109	C	Modelling perceptions of craftsmanship in vehicle interior design (Auto).	Ersal, I et al., 2011	Journal of Engineering Design Vol 22, Iss. 2 p.129
116	C	Engineering psychology and human performance	Wickens, C. *et al.*, 2013	book.
203		Measuring supply chain resilience using a deterministic modelling approach	Soni, U.; Jain, V.; Kumar, S. 2014	Computational & Industrial Eng’g Vol. 74, p. 11
222	C	Defining PQ in the Automotive Industry - An Engineering Approach (Auto).	Stylidis, K.; Wickman, C.; Söderberg, R. 2015	Procedia CIRP, 36, pp.165-170.
230		Craftsmanship evaluation in automotive products (Auto).	Wang, J.; Holden, J., 2000	International Journal of Industrial Engineering Vol. 7, Iss. 4 p. 286

Only those marked ‘C’ in Table 3.1, column 2, presented new or useful information to support this thesis and were critiqued as they contributed sufficiently towards the research. Only paper 222 mentioned Engineers in the title. Those marked ‘Auto’ were related to the automotive industry.

The scope of the literature was principally automotive, but some work has been published in the Service sector where it is used to increase customer satisfaction, footfall or other such factors (Brady and Cronin 2001). Despite being non-automotive, some of these writings were duly considered and did produce some attempts to measure PQ (Chen, Ortega and Wang 2015). Some could have been easily discarded as being totally irrelevant, through being non-automotive, but nonetheless contained arguments of value, as PQ is evident in many products.

In the commercial world of PQ measurement, results are presented as a series of survey results and star-ratings, intended to guide prospective purchasers to one product or another.

Many of these have been reviewed by Kukova (2016) as they do not agree on attributes or factors yet are pored over by individuals and manufacturers alike.

The latter spend considerable sums employing the surveyors as consultants or in this author’s experience creating re-work areas to address particular issues raised by the surveys in a costly post-build rectification process. Re-work is found in most manufactured product, where component parts of an assembly are below standard or missing and the unacceptable or incomplete final product requires some form of rectification. This means inefficiencies: additional costs and time to manufacture.

In order to review the nature of PQ literature, a meta-analysis will be described in this Chapter. It was originally created to be a reference repository for a commercial concern, with open access for all within the company. There was a clear requirement for this data to be collated and analysed critically via a systematic review of the current literature.

3.1.1 Steenkamp’s Hypotheses

As one of the few PQ book authors, there is frequent reference in Steenkamp's work to quality cues and attributes, which are covered elsewhere in this thesis, in the attributes definition section of Chapter 5. Steenkamp insists that in his work, cues can be sensed before consumption or experience of the product, whereas attributes can only be experienced. It could be argued, for example, that an attribute such as colour can be understood before it is experienced. If one were to describe a car as being painted “signal red”, then many people would have a reasonably close expectation of the shade before seeing it on the car.

However, depending upon the vehicle's design and shape, that shade of red may please or displease. Describing a car as “jet black” may also engender a similar expectation, but with less room for shade discrepancies. Similarly, suggesting that seats "look sporty, but comfortable" prior to them being viewed may well set up an expectation of an attribute that need not be experienced. The reality of comfort or not may well be different to the expectation (Erol *et al*. 2014).

PQ is given a whole chapter in Steenkamp’s book ‘*Product Quality*’ from 1989 and is highlighted in the sub-title ‘*An Investigation into the Concept and how it is Perceived by Customers*’.

It is perhaps appropriate and telling that the author chose to capitalise certain words in the sub-title which have greatest relevance here. In Chapter 4 of this book, Steenkamp brings in PQ by titling the section ‘*The PQ Approach*’ (Steenkamp 1989: 58). Much of the rest of the book is devoted to analysing PQ and discussing conceptual models of the quality perception process. Empirical data is generated and tested, and hypotheses proposed. As this work is one of the foremost in PQ to date, it is worth listing the hypotheses and some other details of his work. Table 3.3 following will show a summary.

Below is a summary of Steenkamp's Hypotheses in Table 3.2. His full hypotheses are shown in the chapter Appendix, 3.1.

Table 3.2. Steenkamp's hypotheses in summary

Ref.	Steenkamp's Hypotheses summary	Upheld or not
H_1	"Quality attributes act as intervening variable.	Upheld
H_2	"Experience attributes are weighted more heavily than are credence judgements."	Upheld
H_3	"Consumers are more able to use quality cues than credence attributes."	Upheld
H_{4a}	"The higher the predictive value of a cue, the more important that cue is."	Upheld
H_{4b}	"The higher the confidence value of a cue, the more important that cue is."	Upheld
H_{4c}	"Intrinsic cues are more important than extrinsic cues."	Upheld
H_5	"The role of quality attributes in the PQ process is greater for experienced than inexperienced consumers."	Not upheld
H_6	"The role of quality attributes in the PQ process is greater for quality-conscious consumers."	Upheld
H_7	"Consumers experiencing high risk used fewer quality cues in the PQ process than consumers experiencing low risk."	Upheld
H_8	"Higher-educated consumers use more cues in the quality perception process than lower-educated consumers."	Partially upheld
H_9	"Cue interactions are more numerous in the PQ process of higher-educated consumers than in the PQ process of lower-educated consumers."	Partially upheld

It is interesting to note how many of his hypotheses are upheld by empirical studies. Steenkamp is still active in the PQ research arena, in particular with reference to PQ and its relationship with marketing strategies. His model of the four approaches to product quality in Fig. 3.2 shows the PQ element under an over-arching metaphysical approach.

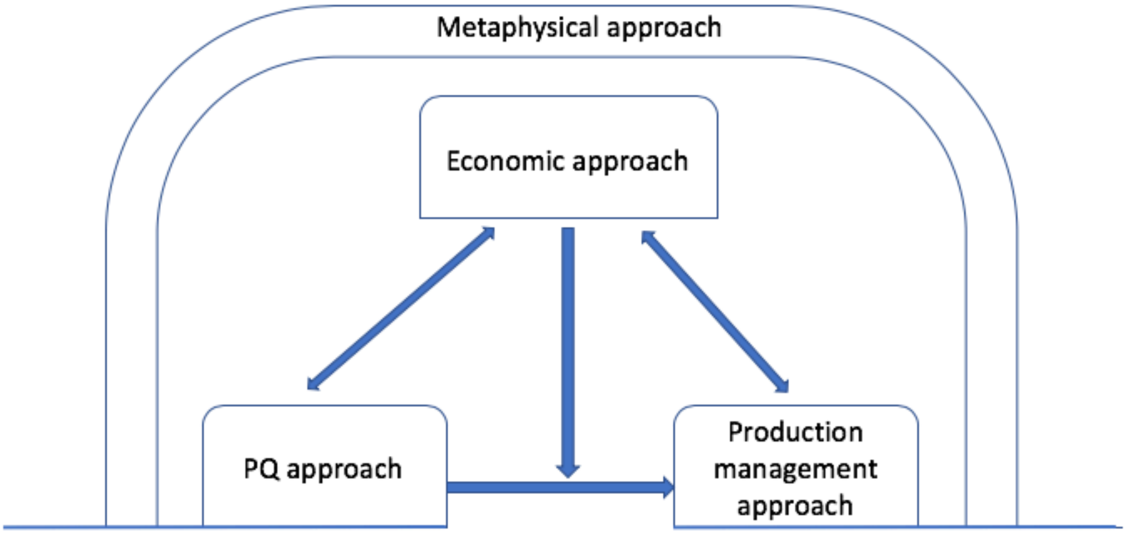


Fig. 3.2. Steenkamp's four approaches (Steenkamp 1989: 96).

In all such work the customer is key, such as Yee and San (2011) who surveyed 2000 Malaysian participants to examine what factors influenced their decision to buy an automobile. They also researched how PQ, perceived value and perceived risk were related to each other. A positive correlation was demonstrated between these three elements of PQ, PV and PR, with the first two showing the strongest relationship. They showed that PQ has a positive relationship on the buying decision. Purchase is a dependent variable, whereas PQ, PV and PR are independent (Yee and San 2011). Yee and San considered previous work on the purchasing decision (from (Blackwell, Miniard et al. 2006) and looked closely at the first five:

1. Need recognition
2. Search for information }
3. Pre-purchase evaluation alternatives } See image in Fig. 5.2
4. Purchase }
5. Consumption }
6. Post-consumption evaluation
7. Divestment

These researchers also put the public, the customer, at the centre of their research and investigation.

Other researchers did so, from the early days of PQ study and more recently, thus further validating the user as a central core to this research, as described in Chapter 6 (Zeithaml 1988; Tonetto and Desmet 2016).

3.2 Core Methodologies used in thesis for knowledge elicitation and organisation

Three methodologies will be described here to examine how knowledge is elicitated from human discourse, both written and spoken. ISM was introduced earlier in the thesis and will be explained in the section following. This is believed to be the first use of ISM to examine PQ attributes. Psychology and HF have also been introduced earlier and will also follow described in more detail. This illustrates the multi-disciplinary nature of this thesis

3.2.1 The use of ISM to analyse attributes.

ISM has been employed successfully, but in limited applications to assess complex commercial, scientific and even military issues and the process flow is shown following in Fig. 3.3. ISM was the chosen methodology here due to its ability to create patterns from seemingly disconnected and even contradictory factors; in this case automotive product attributes. ISM was selected as a tool to assess attributes for their relationship and hierarchy after it was successfully used in a paper on attributes used in Supplier Quality in a previous study (Hughes et al. 2016).

Warfield, the original promoter of ISM, stated that “By continuing to compare Alternatives in pairs, using the process just described, a relationship of preference is built up on the Alternatives. This means that one can draw a tentative preference structure for the set of Alternatives based on the paired comparisons of Alternatives”. ISM was developed in Columbus, Ohio, at the Battelle Memorial Institute in 1972-74 (Warfield 1974). Its use spread quickly to Japan and later to Brazil, Germany, England, India, and elsewhere.

The ISM process looks for associations between often disparate members of a set by a group of people through facilitated discussions.

It is a learning process for all participants, with ISM highlighting differences and links between the set members. ISM can use computing resource to remove the tedious manipulation of the matrices created and looking for the links between each member. The result of the process is the creation of digraphs and charts showing levels of relationships and groupings thereof. The use of these will be presented in Chapter 5.

Despite its clear application to complex issues, a simple search in Scopus reveals only 164 final conference papers in the last 5 years which employed the technique, possibly due to its complexity and the need for good facilitation, group discussion and accuracy in transposing data. Of these, inserting “automotive” into the search field revealed only 27 papers, of which upon further examination, less than half were strictly about vehicle production or engineering (Elsevier 2019).

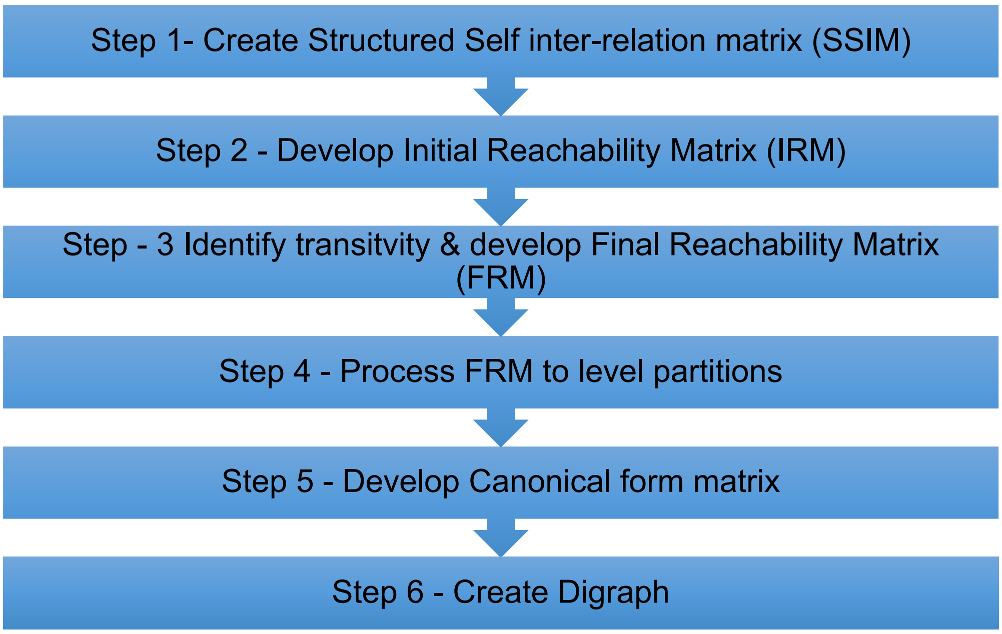


Fig. 3.3. The ISM process flow.

The detail behind the employment of ISM to look at relationships between attributes is shown the relevant chapter on the OEM and PQ, Chapter 5.
The ISM process is partnered in this thesis by the use of mental models to use psychological tools and present a multi-disciplinary assessment of PQ in the automotive industry. We shall now consider mental models.

3.2.2 Mental models to describe and illustrate thought processes

Mental models have been introduced in section 1.3.2, mentioned again in the Audit process in section 2.2.1, and will be referred to throughout this thesis as a pictorial way of presenting the way people think. People construct mental models to make sense for themselves of the world around them (Johnson-Laird 1983: 10). It relies upon many, often unrelated stimuli.

Then people seek to link stimuli to the model they have created in their minds (Johnson-Laird 1983: 150). Perception – what we are discussing here – is a process that creates a three-dimensional active scale model of a person's environment and that becomes the person's reality (Johnson-Laird 1983: 423). Forbus and Gentner even titled their 1997 paper "Qualitative mental models: Simulations or memories?" (1997: 1). Their response to this titular question was "some of both" and that qualitative models (the sort in which we are interested to assess PQ) would be best represented by a hybrid model, incorporating comparisons and experience as well as abstraction to aid their understanding, in this case of a product's PQ.

Having looked at ISM and mental models as information elicitation tools, we shall now look at the information organisation of the literature review and meta-data study design, materials and procedure employed.

3.2.3 The Kano thread

Core methodologies used in this thesis of ISM and Mental Models will be discussed in each of the three study Chapters 4, 5 and 6.

The linking thread of Kano theory introduced in 1.6 is a key item from the subject matter research described in this chapter. It will also be related to each study at the head of each chapter (4, 5 and 6).

3.3 Design of meta-data study

The approach to be adopted here was to base the thesis in the current research, such as mental models, which was developing quickly and if possible, attempt to establish links with other researchers to follow these advances. As mentioned in Chapter 1.1, attempts by the company originally sponsoring the research to find out more about PQ locally (in the UK Midlands) had not been successful. So, a diligent search for what was available internationally and a way of recording and presenting it was vital.

From the early stages of the research, a simple Microsoft Excel-based matrix was envisaged, purely as a repository for the reading stage. For the sponsoring company and the needs of the research, this was seen as a mutually beneficial arrangement. The company employees could access the information and the researcher developed the study tools to ground the thesis.

Regular meetings between the two parties created a format that suited both and stored the information locally, but with the necessary copyright protection in place. The format was to be straightforward, easy to navigate and based upon the Company structure (see Fig. 4.1).

As it was an Engineering Centre, the structure was that of most such enterprises, whereby CoC's (Centres of Competence) were the departmental disciplines. These CoC's were listed in alphabetical order down the vertical left-hand side of the matrix. As reading material was collected, it became apparent that further, non-Engineering disciplines needed to be added, so PM, (Programme Management) and S&M, (Sales and Marketing) appear in the listings. Much of the research on PQ concerned the subject of Brand and Brand Equity, which is clearly the responsibility of S&M.

Across the horizontal axis was created a series of categories which sought to guide the novice or casual researcher as to whether a piece of reading was considered to be of interest from experience in the automotive industry. The title of the learned paper, conference proceedings or book was next on the horizontal axis and listed as a hyperlink, followed by a reference number automatically generated by the RefWorks tool.

A short description followed across the sheet, so that any reader could more quickly assess the relevance of the information to his or her needs, especially if the title was insufficiently clear or short.

The next column stored a colour-coded cell, which was green with a suitable hyperlink added to a Critique of the paper. (See Fig. 3.4 - colour removed here for clarity).

Following the critique was another colour-coded cell, which declared in this author's opinion and as a result of the Critique, whether the material was strongly or barely relevant to the PhD subject of PQ. Also, an indication of the (original) thesis chapter was given.

3.4 Materials and tools employed

The tools employed in the Literature Review are:

1. RefWorks – web-based bibliographic control and storage system.
2. Microsoft Excel – PC-based spread sheet software.
3. Coventry University pro-forma template for critiquing literature materials using Microsoft Word(Coventry University CAW 2016).
4. A template was generated as a Matrix for summarising literature and identifying useful material for the PhD, again using Excel, as detailed in section 3.3.3 and below.

3.5 Procedure - development of the matrix

After a period of use, it was proposed to make the device more suitable for use by perhaps another automotive Company, but specifically a research tool itself.

The ability to draw together ideas and concepts from the research, group them and draw statistical conclusions from such groupings was vital. This may have given a different slant to the research or confirmed a direction in which it should have been heading. Therefore, more columns were added after the Thesis Chapter cell to represent these developments.

A column for 'Methodology' employed in the material was a free-text field, which is not always clearly identified in a paper, or can show a mix of methods.

This was followed by a ‘Perspective’ column heading, itself split into three sub-columns of “User’, ‘Mix’ and ‘Engineering’. There being no absolute measure for these distinctions, it was up to the researcher to make them. The final major column of ‘Metrics’ was also split into sub-categories of ‘Subjective’ and ‘Objective’. Again, these distinctions were not always so clear.

The researcher’s experience and judgement decided the split. In some cases, both columns were ticked as it was considered that the writer of the material had used both types of metrics.

The resultant enlarged matrix could now be used for some statistical analysis. Data could be collected from the summation of entries in each of the additional columns, this making the device more of a research tool than a mere repository of information. Also, the mere presence of an entry in the Critique column indicated a paper of more than passing interest and simple colour-coding was also employed to denote special items of interest. Fig. 3.4 following shows the column headings and format

Engineering CoCs	Paper title	Ref. No.	Short description	Short article (no critique)	Critique and summary	Relevance to PhD studies- Thesis chapter	Methodology	Perspective			Metrics			
					Green = critique written	Green = relevant Amber = some relevance		User	Mix	Engineering	Subjective	Objective	Qualitative	Quantitative

Fig.3.4. Format of reading review matrix

The column headed ‘Critique and Summary’ was added once the research was begun in earnest as a way of structurally assessing the existing PQ research in the public domain. A standard process was then used to read and critique each piece of reading by following a pro-forma route.

In order to gain the most out of the reading, over 100 Critiques were written of only the most relevant sources and once having identified the paper Aims, Methodology, Results, Discussion and Conclusions, the same questions were asked of each paper, shown following in Fig. 3.5.

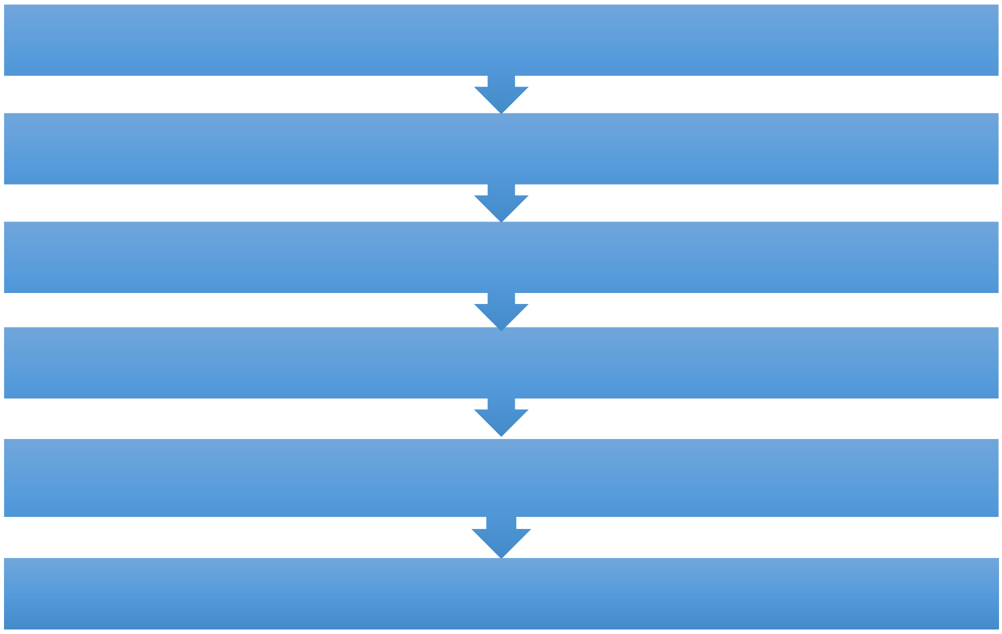


Fig.3.5. Process flow for critiques (Coventry University CAW 2016)

Books were treated in much the same way but were summarised by picking out useful sections and quotable references in a table for possible use in the thesis. Again, there are many books and much information on pure manufactured product quality (Crosby 1984, Garvin 1988, Shingo 1986, Taguchi 1986); but precious few (Gallo 2012) on PQ.

The time-frame for the collection and analysis of the background literature was the whole duration of the thesis study period, from 2013 to 2019 and covered over 330 individual reference items.

Appendices A3.2 to A3.6 show sample extracts from the matrix for various CoC's, such as BO (Body Structure), Design, EE (Electrical Engineering), EI (Interior Trim, S&M (Sales & Marketing) and EQ (Engineering Quality). VIP's (Very Important Papers) are highlighted in yellow. Further appendices show in A3.7 and A3.8 how the identification number from the RefWorks (legacy) software was used to check that the reference had (or had not) been included in the thesis. A further check shown in these images of Excel tables was made if a critique of the paper had been written. This generally indicated a VIP. Finally, the chapter appendix also shows in A3.9 a complete image of a critique.

3.6 Results of matrix usage

The results obtained from simple summations of the occurrence of entries in each column, are of some value in showing where there is emphasis in the current research and where there are gaps.

Such statistics are shown below in Table 3.3 (Note that some perspective scores, such as Subjectivity and Objectivity, were often both used by the researchers in some items). We will return to these statistics in Chapter 5.1 and Fig. 5.1, with reference to the OEM and attributes.

Table 3.3. Analysis of Matrix reading

Analysis	**Research items (papers, books,etc)**
Total items read	330+ (100+ critiqued)
	Perspective across all items-
User	142
Mix	132
Engineering	11
Metric –	
Subjective	184
Objective	149
Quantitative	256
Qualitative	83

If one considers the Engineering discipline or Company department to which the research material is most closely linked, then the spread is as follows in Fig.3.6.

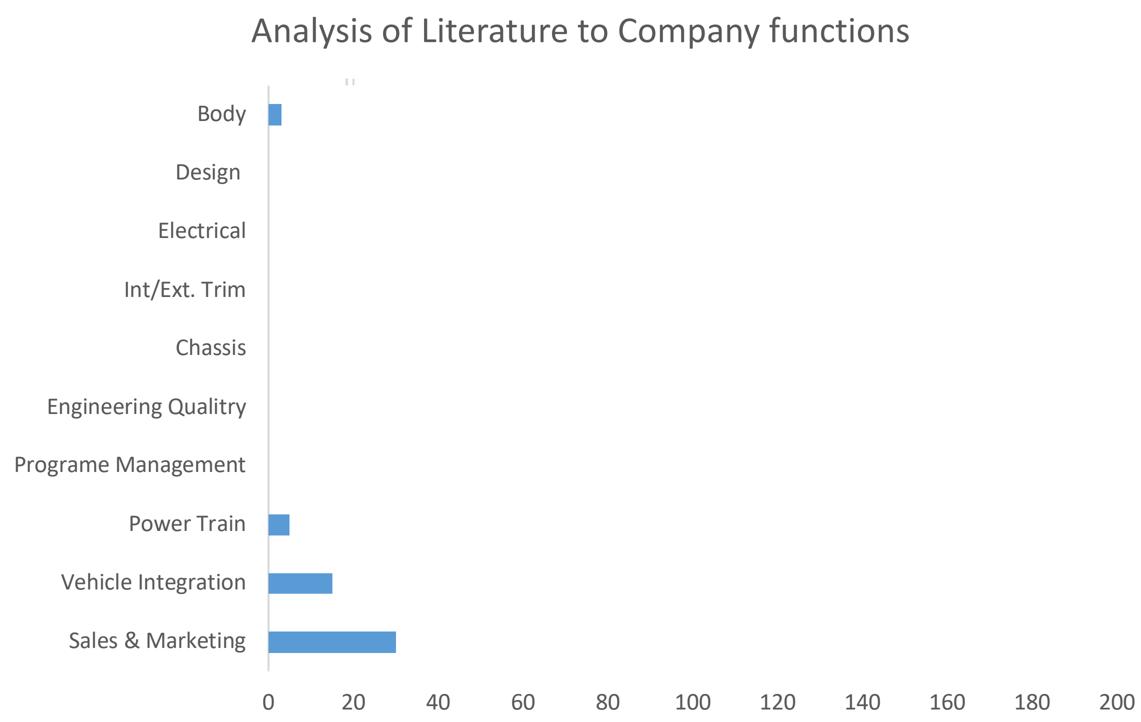


Fig.3.6. Analysis of reading aligned to engineering disciplines

Fig. 3.6 above shows that there are very few specific PQ issues with material written about issues such as Chassis or Body Engineering. This is interesting when compared with the attributes discussed in Chapter 5, where the OEM view of PQ is investigated, where for example Wheels and Tyres emerges as a significant attribute. This is a qualitative view of the subjects and their appropriate functional 'home'. Although touch and tactility have been mentioned in Chapter 2 under senses in section 2.1.4, these issues will be examined later in the thesis, but are principally the domain of the Trim Engineers, yet little is shown against this function.

3.7 Discussion of Matrix approach

The Matrix has served the thesis immeasurably in terms of collating and evaluating the background reading and research, with the added benefit of making this researcher more diligent and organised.

The division into Engineering CoCs or disciplines was intended to serve the initial sponsoring Company, but has been less useful subsequently, except where the correct CoC was not obvious, which led to the inclusion of PMD (Programme Management Department) and S&M (Sales and Marketing), particularly for those papers which were concerning Brand and Brand Equity. The matrix was originally hosted on the Company's intranet with hyper-links to documents, where copyright allowed copies to be held. Where copyright did not allow, this writer's summaries and critiques were accessible.

The Matrix makes it possible to easily search for key words, titles and links directly to the RefWorks tool through the column with the reference number. It is manually updated every time a new reference of value is discovered.

The statistics show that of over 330 listed items (some other papers were read but rejected as not useful or contributing to the research), 43% showed a strong User bias, with 40% mixing Engineering and the User, with 3% of items that used Engineering as a bias. The perspective taken by the material showed a 56% Subjectivity leaning, so more than half the material taking this viewpoint, not surprising as we are dealing with an opinion-rich concept in PQ. However, Objectivity was not far behind with 46%. Qualitative measures in the reading scored 78% against Quantitative showing 25% results. As this research is looking to promote a measure of Qualitative aspects, the chosen research material serves the process well.

There now follows a short SWOT analysis (Strengths, Weaknesses, Opportunities and Threats) of the Matrix approach, as it was considered a valuable tool to the consultancy for which it was designed and may represent a practical and helpful method to others faced with an array of particularly descriptive data.

3.7.1 SWOT Analysis of Matrix

It was considered a useful exercise to conduct a SWOT analysis on the Matrix approach to promote the furthering of this research within the Consultancy. At this point of the research, Quality Tools via Six Sigma were being taught widely within the Company, so use of one such tool was timely and appropriate.

Strengths –

- The Matrix stores all research material in one place.
- It enforces discipline towards its own maintenance.
- It links to RefWorks.
- Statistical analysis has been performed upon the material.
- For the original Sponsoring Company, the division into Engineering CoC's was useful.

Weaknesses –

- The Matrix required constant attention and updates.
- The original use became irrelevant, but a reconsideration and evolvement showed even greater uses.

Opportunities –

- The Matrix could be of use commercially to another Automotive Engineering company.
- The continuance of the discipline provides a backbone for the research.
- Other researchers may find it a useful approach.

Threats –

- The time absorbed in the Matrix's creation, stripping of original sponsoring Company hyper-links and its maintenance have all been extensive.
- The manual nature of updates and entries means that it may not have been the best use of time.
- On account of the manual updating process, some items could be missed.

3.7.2 Sample Critiques of material

The material discovered through the research was assessed for the matrix and as indicated a column was created for ‘Critiques and summary’. Each Critique itself followed a pro-forma route.

In order to gain the most out of the reading, over 100 Critiques were written and once having identified the paper Aims, Methodology, Results, Discussion and Conclusions, the same questions were asked of each paper, as described earlier in section 2.4.

For example, 1: “Measurement of Sensory and Cultural Influences on Haptic Quality Perceptions of Vehicle Interiors”(van Laack 2014).

Some works were by title and content of great value. The result of the six questions on this source from Fig. 3.4 are:

1. What are researchers trying to find out? *See Research Questions below.*
2. Why is the research so important? *The research can have a commercial application.*
3. What things were measured? *Haptic measurements of stick-slip, etc.*
4. What were the results? *Similar across cultures, but measurable reliably.*
5. What do the authors conclude? *See detail below*. What factors do they attribute to their findings? *Cultural differences exist. Repeatable measurements were taken and compared.*
6. Can you accept the findings as true? *Yes, a good piece of work.*

Van Laack’s research questions were:

RQ1. “Which measurable values influence the human perception of haptic and tactile descriptors such as friction, stick-slip, stickiness and temperature perception?”

RQ2. “How can the influencing values be measured reproducibly?”

RQ3. “How can the measured characteristic be linked to the subjective perception of customers?”

RQ4. “To what extent does the cultural background influence the perception and the rating of vehicle interior quality and quality attributes?’

The conclusion on the research by Van Laack (2014) was that customer clinics showed that descriptors in RQ 1 can be measured reliably. There are similarities in haptic perception across cultures.

Interior design, colours and appearance were shown to be received and perceived differently across cultures. A reliable method of measuring these differences was found and tested.

For example, 2: "Chinese Consumers' Perception of Imported Versus Domestic Pork Quality"(Chen, Ortega and Wang 2015)

Other works were not so obvious yet contained gems of information on PQ in other industries, such as food.

> This latter research, despite having the PQ of pork (imported versus home-grown) in the Chinese market as a subject, proposed a PQ measure, where Y is PQ.
>
> $Y_{ij} = X'_{ij}B_j + u_{ij}$
>
> (where *i* denotes an individual*; j* =1, 2….*m*, indicates the *j*th equation; X'_{ij} is individual *i*'s independent variable vector of the *j*th equation; and u_{ij} is the error term).

The critique summary was that food/car quality is a subjective game. For both commodities, there are extrinsic and intrinsic quality cues.

A user-focused analysis needs to be adopted to look at issues from a consumer's point of view. As with cars, pork has many characteristics by which it is judged, and the Country of Origin can play a part.

Naturally, in any research, some material represents 'stand-out' quality, or as labelled in this thesis, VIP's (Very Important Papers).

Such works are those upon whose foundations are built more research and thus the subject grows in depth of knowledge. Of these, two are selected here. One looks at PQ from the very early stages of the design of a vehicle and the other from a very human viewpoint, that of "Design and Emotion".

For example, 3: "Visualizing the Effects of Geometrical Variation on Perceived Quality in Early Phases" (Wagersten 2013).

Derived from the work of a number of researchers at Chalmers University in Gothenburg and supported by Volvo Cars, the early recognition and impact of PQ in the Design process was the subject of several papers, culminating in a Thesis The author, Ola Wagerston, declared that:

“The work in this thesis is aimed to support and structure the work around simulation and visualization activities to better facilitate early judgments of perceived quality of split-lines.” (Wagersten 2013: 3).

By using the pro-forma and the six questions, the shape and results of a later Critique were more in depth and useful, such as that conducted on some work by another group at Delft University (Fokkinga*, et al*. 2014).
This paper was very much of the ‘V.I.P.’ type and the assessment was as follows:

“Conclusions

It works. Experience of a product is in layers, which intertwine and complement. Experience and behaviour cannot be separated.

Review

1. What are researchers trying to find out? *A V.I.P., which meets the aim of looking at product impact, experience and effect.*
2. Why is the research so important? *Can be used to analyse current product and future.*
3. What things were measured? *See model.*
4. What were the results? *See Smart car example.*
5. What do the authors conclude? *What factors do they attribute to their findings? As above.*
6. Can you accept the findings as true? *Yes. Great piece of work with no formulae!!”*

Some paper critiques were not perceived as positive, such as that by Christodoulides, Michaelidou and Li (2009), and were not as useful to this thesis development as their title had suggested - 'Measuring Perceived Brand Luxury: An Evaluation of the BLI Scale'.

As part of this thesis, the development of a measure of PQ had been a long-standing aim, so the chance that one had already been created was of great interest. However, there was little to be gained from this paper, as the measure was not new and merely a numerical score.

3.8 Conclusions

The principal methodologies described here: mental models, ISM and the matrix of literature will form the basis for the remainder of this thesis. ISM is a useful tool to look at relationships between apparently disparate and unrelated concepts, such as automotive attributes. Mental models will be used to give shape to the way people think in the three following surveys of Engineers, the OEM and customers. Mental models are a useful, visual method of showing pictorially a person's thought processes. The aim of using such methods was to give a better structure to a multi-disciplinary approach as presented herein.

For this research, the efforts involved in creating the Matrix have been worthwhile. The benefits are extolled in the SWOT Analysis and experience has shown these outweigh any negative points. The concept of the Matrix could be useful to other students. The enforced change from an instrument requested by the original sponsoring Company to an on-going research tool with enhanced features meant that from an event which could possible derail a PhD came a much-loved assistant, disciplinary device and focus for research background.

The ability to extract statistics is also evidence that this research subject is worthwhile, as there is little recent material currently available.

The development of a more structured method of reading and assessing material was practical and useful - a set of regular questions to respond to at the conclusion of a document's reading was beneficial in the following ways:

- It meant that responses had to be given in the author's own words
- There was a possibility of comparing research assessed by this method
- The Critique (which could run to two or three pages) and to some extent the responses could be used as building blocks in this thesis
- Such a method ensured that thesis writing was continuous and structured.

Chapter 4 - The Engineer’s role in creating Automotive PQ

4.1Chapter hypotheses

- Engineers create PQ.
- PQ must be managed and controlled during its creation.

4.2 Background

This is the first of three surveys, that look at the progress of PQ from its creation, through the management of PQ by the manufacturer, to its consumption or experience by the customer. Three surveys were carried out in order to follow PQ as a holistic process from creation to consumption, which as an issue has been somewhat neglected in the literature. Across several decades, PQ has been seen being created, promoted and neglected, with attempts (successful and otherwise) by manufacturers to manage and uphold PQ. First-hand experience of customers on the receiving end of such efforts also colour this research. The problem space is therefore how to analyse this three-stage process and therefore questions were asked of the participants at each point along the time-line to understand PQ further.

The context for this survey was provided by the Quality Manager (to whom this author then reported) of an Automotive Consultancy wanting to understand what the Engineers knew about PQ and how they related to its creation. Therefore, a review of the current literature was made to see what was already in the public domain regarding Engineers and PQ.

The main Literature review for this thesis was detailed in the relevant section earlier in this thesis (see Chapter 3). Of the 330-plus sources reviewed and critiqued for the subject of PQ, less than 10% of those sources examined the role of the Design Engineer in the creation of PQ.

Nonetheless, many of these were created by the Department of Product and Production Development at Chalmers University, working in conjunction with Volvo Cars in Gothenburg, Sweden and therefore have an academic basis with a commercial corroboration.

Little is published by other OEM's, so this window on the automotive industry is a vital repository of useful data, although an insight into the detail behind tactility and PQ inside Ford Motor Company is very detailed (van Laack 2014). It was clear however from these sources, that the role of the Engineer in creating PQ was key. This gave rise to the Research Question to look at what that role actually represented; were Engineers aware of PQ and where it was created, who was responsible for PQ, when and how it was delivered within a vehicle programme and how were benchmarks of PQ arrived at?
Past literature has shown a fairly weak representation of research work looking at the role of Automotive Engineers; only 14 papers on PQ in the Literature Review for this thesis featured the word 'Engineer' following a simple word-search in their text (see Fig. 3.4). It was therefore worth analysing the role and contribution of these Engineers. Engineering was at the core of the daily operation of the Company assessed. Indeed, the term CoC or Centre of Competence was often applied to describe each design discipline, as shown in Fig. 4.1.

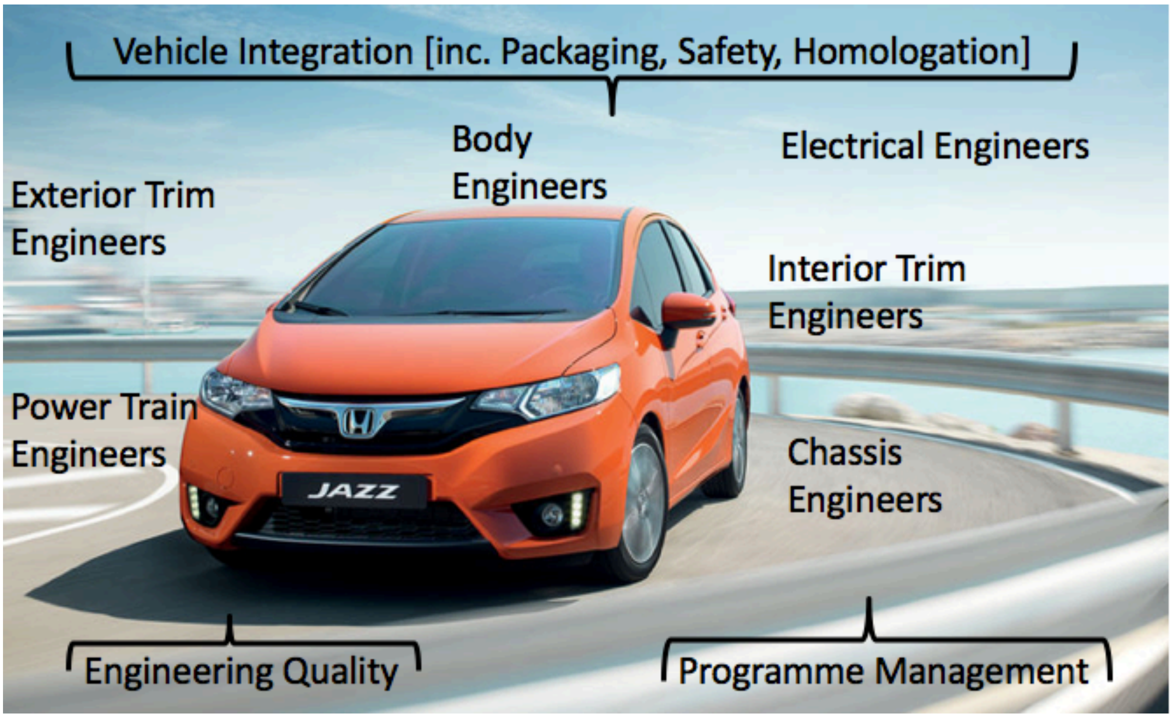


Fig. 4.1. The Engineering Centres of Competence in a typical Automotive Engineering Company (Honda 2018).

In this thesis, the word ‘Milestone’ will be used. Milestones as shown in Table 4.1 (or MS) following are just that; they are points along the time-line journey of the creation of a product, in which it matures from MS 1 (Product Concept) to MS 9 (Volume manufacture or Job 1).

Table 4.1. Example of project milestones

Milestone	**Title**	**Description and activities**
MS 1	Concept	Concept(s) developed; styling models created
MS 2	PA1	Concept selected; Initial Programme funding approved
MS 3	Initial Builds	First prototypes or mules built
MS 4	PP	Programme proving, major funding approved
MS 5	VP	Validation Prototypes
MS 6	QP	Quality Proving, parts made on production tools
MS 7	M Build	Quality Maturation
MS 8	Pre-volume	Rising volume rate
MS 9	Volume	Intended volume rate

Some manufactures use less milestones, others more than the example shown, which is a fairly common series of pre-volume design and development phases from an early concept through to final volume production.

4.3 Introduction

This section will now look in detail at the creators of PQ, the Engineers. Theresulting survey was also supported by the Company Quality Manager seeking guidance on PQ and its creation through to deployment. This Manager had consulted academia and the Quality function resources, seeking validation of then currently held PQ beliefs. The UK Consultancy was a design and development arm of a major international automotive manufacturer and the pursuit of PQ definitions and measures were being investigated across the organisation. A logical start point was to survey the creators of PQ in the Design function.

The “How is PQ (created)” was investigated in this survey, following the need to determine exactly how PQ was crafted, the following Research questions were postulated:

RQ1 Do Engineers create PQ and are they aware of doing so?

RQ2 Is there a Leader, or Owner of PQ in the product creation process?

RQ3 Do Engineers have a view on how to manage and deliver PQ into products?

4.3.1The linking thread of Kano

As discussed previously in Chapters 1.6, 2 and 3.1, Kano's model has been shown to align closely with the study of PQ. In this study on Engineers creating PQ, Kano again is associated closely with the duties and process of engineering. Engineers are given targets, parameters and boundaries to work to and within. These should align with what the customer wants (or what the OEM believes they will want) and perhaps by using a Quality Tool such as QFD, the OEM can turn these 'wants' into 'hows' (Matzler and Hinterhuber 1998).

Kano's model gives more structure to features and attributes considered for inclusion into the design and specificationEngineers will look at current designs or specifications and in conjunction with other functions such as Sales and Marketing, use the Kano model to decide whether the passage of time has changed the position on the graph. Kano remains a key tool for any engineer.

We shall now consider why this group of people were selected to be studied more closely in the search for a greater understanding of PQ.

4.3.2 Why Engineers?

In any automotive manufacturer, the Design function is populated by Engineers. They take the direction from the Styling Studio, who themselves have been given a product intention decided upon by Marketing.

Engineers were the most populous professionals within the Company and yet seemed to be least aware of PQ (see responses to Questions 1 to 3) and its importance, despite the best efforts of the Quality department. Therefore, with a readily available audience of Engineers, the Quality team asked that the survey be directed towards those who directly create and influence PQ.

Although the Quality department had promoted PQ sessions to assess competitor vehicles, these were structured and process-driven by their nature. However, during such sessions, it was clear that there existed amongst the engineering population, a body of knowledge and experience previously untapped.

As PQ is set early in the design process (Wagerston 2013), it was vital that the views of Design Engineers were sought. The Design Director of an OEM was also interviewed. His view was that the ‘home’ for PQ was in the Design Studio and that a team of PQ Engineers should reside under his direction. This validated the choice of conducting a first survey amongst these Engineers.

In designing a vehicle, the initial concepts are created by Stylists working in the Design Studio. They take cues from current and predicted fashion, plus past successes given a new ‘twist’, such as the BMW Mini, Triumph Bonneville and Fiat 500. These ‘retro’ products have spawned whole ranges of cars and motorcycles.

Once the concepts have been presented into 2-D sketches and 3-D models, the work of the Component and Design Engineers begins, so very early on in the process. Both groups are able to impact the PQ of a product from this point onwards.

Studio Engineers therefore start the PQ process, beginning with the Stylist’s original sketches and models. An early contention for both parties is what the Stylist wants and that which the Engineer knows from experience is possible or not.

It is a regular bone of contention: for example, a Stylist may wish for a very sharp detail or styling line across or along the edge of a panel. The Engineer has to be bound by market-specific regulations which will permit radii only above a certain minimum, to avoid pedestrian injury in case of impact or collision.

External PQ (that which is usually seen first) is created through these discussions, with the Engineers creating the forms and panels in early, usually computer-generated formats. It has been found to be that here lies the major impact on PQ (Hazra et al. 2008; Wagersten, Wickman and Söderberg 2009).

Many hours will be spent looking either at a clay model (full-size or scale) or more likely a full or larger sized CAD representation of detail areas of a vehicle. From experience, these are intense, detailed sessions using ‘zebra-stripes’ (see Fig. 4.2) across panels to give those viewing a better idea of whether one surface blends into another or not, particularly across split lines. In the case of a Mercedes Gelandewagen, across purposefully very wide splits, see Fig. 4.3.

Wide split-lines are found on agricultural and off-highway construction equipment, so the link with these tough, go-anywhere vehicles is made with the G-Wagen through this ‘feature’. Added to this, a tight/narrow evenly parallel gap is more expensive to create through accurate tooling than a wide one.

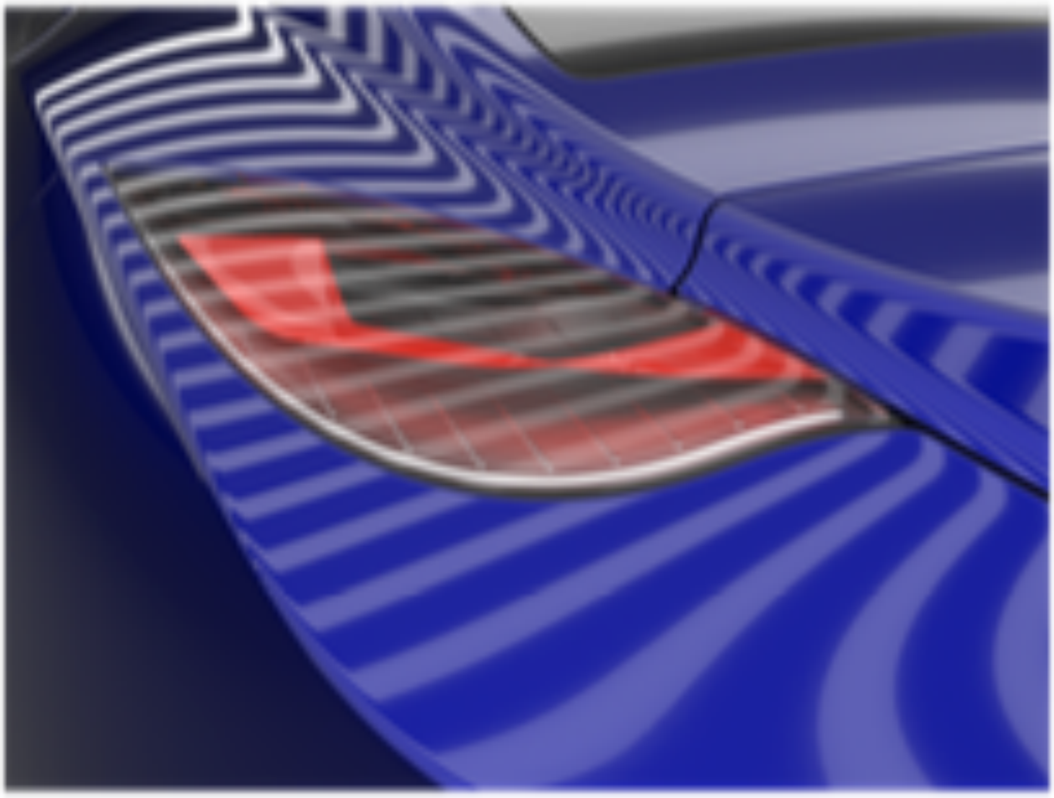


Fig. 4.2. Styling ‘zebra stripes’, an aid to panel design and assessment (Reese 2015), used with permission.

Fig. 4.3. Example of split-lines (Author)

It will be apparent in the finished article if the Engineers have not conducted these assessments properly during development. Subtle, or not so subtle changes in form will be detected by the human eye, even an inexperienced one (Hazra et al. 2008). In order to capture the Engineers' thoughts on PQ, the survey was designed to be challenging, yet easy to complete and to link into their normal work on surfacing, gaps and profiles, etc.

4.4 Method

The chosen method here was to use a survey. This was dictated by the researcher's employer/PhD sponsor at the time. It was important at the time to understand what the Engineers knew and thought about PQ, so asking them directly yet anonymously by an internal survey was selected as a Method.

4.4.1 Survey Design

The design of the survey was seen as an experiment performed on behalf of the Quality Department, following failure to find a local PQ expert within the tertiary education sector, who could distil PQ measurement down simplistically.

Therefore, using the opportunity to sample the Company workforce cheaply, easily and quickly, this survey was created. All participants filled out the same on-line questions until 50 responses were received. This number was considered by the Quality Manager to be statistically sufficient and not so much data that the analysis would be too time-consuming.

As described previously in "Why Engineers", with a workforce of the latter, the Quality team asked that the survey be conducted with those who directly create and influence PQ. As the preceding section shows, the audience of experienced Engineers was targeted to be the respondents to the first survey. This was for a number of reasons:

1. The Engineers were co-existing in one building in two adjoining rooms.
2. They could be addressed directly by face-to-face contact in order to set the scene for the roll-out of a survey.
3. Many of them had already experienced PQ in other OEMs, such as VW, Bentley, BMW and Tier 1 suppliers, before working in their current role.
4. Some PQ elements were already discussion points in the Engineers' roles, such as surfacing (see Fig. 4.2 earlier, which showed how 'zebra stripes' are used to assess for surface changes and form flow).
5. A request from another PhD student to be allowed to discuss his thesis on seat comfort was received with interest by the Interior Trim section and this initiated PQ discussion amongst Engineers and their management (Erol *et al.* 2014).

The survey was designed in conjunction with, and for the client, (an Engineering Design Centre) to look at various aspects of PQ creation by Engineers.

Awareness was to be tested, (via three questions), as it was clear that although considerable information existed about PQ studies on competitor cars, not all Engineers were familiar with the PQ material or its location. An assessment of the understanding of participants as to where PQ was created had to be established (two questions).

Who was responsible as PQ Leader was tested via one question and seven questions dealt with the delivery of PQ throughout a vehicle programme. One question was asked on Benchmarking of PQ and the final question was inserted at the insistence of the Quality Manager to encourage debate about the more personal views of Engineers and PQ with regard to wider products and services which they bought. The design of the survey sought to build up the respondent from simple Yes/No types of questions to more detailed and thoughtful ones. As creators of PQ, it was important that the survey be designed around the intended participants, the Design Engineers.

4.4.2 Participants

Across a workforce of about 250 Engineers, an open invitation was presented to contribute to the study. 98% of respondents were male, with a mean age of 45yrs. Considerable automotive experience was demonstrated, and this had come from Engineers having worked in a number of different manufacturers. Respondents came from all aspects of automotive design disciplines, such as Body, Chassis, Electrical, Power Train, Seating, Trim, Styling and support functions, such as Quality and Programme Management. Once 50 responses had been received over 3 months, the Quality Manager was satisfied, and the survey closed upon their instruction.

4.4.3 Materials

The survey software chosen for the exercise was dictated by the client and was called 'Smart Survey'. This was not Bristol Online, as prescribed by Coventry University, but a very similar format. Any ethical issues were governed by the HR policies and procedures extant in the Company. Question types - Closed or Open - are shown in Table 4.2 following, as are the Themes (A to F) investigated through the questions. The Themes, or grouped questions came from discussions with the Quality Manager, as part of the survey design and what was hoped for as an outcome.

Theme A was about PQ Awareness amongst Engineers.

Theme B covered the position of PQ in the vehicle development process (as shown in the Milestone example flow-chart in Table 4.1).

Theme C looked at the responsibility for PQ - the process leadership and ownership.

Theme D was the main thrust of the survey - and typically for an OEM as detailed in the title for section 1.2 in the thesis Background - is the delivery of PQ. Vehicle manufactures are very focused upon delivering objectives, designs, components, projects, etc.

Theme E is always an OEM focus – looking at what other companies do and investigates the search for PQ benchmarks.

Theme F wraps up by asking personal questions and eliciting the value to a person of PQ. This ties in well with the final survey chapter 6 on customers and users.

The information sought via each theme is summarised in Table 4.3.

Table 4.2. Types of questions and the PQ themes (A to F) in the Engineer's survey

Question no.	Subject	Theme		Type	Validity to thesis
1	Awareness	A	PQ Awareness amongst Engineers.	Closed	Yes
2	Reports			Closed	No
3	Reports			Closed	No
4	VTS	B	The position of PQ in the vehicle development process.	Closed	Yes
5	Where PQ fits			Open	Yes
6	Responsibility	C	PQ process leadership and ownership.	Open	No
7	PQ Target	D	The delivery of PQ.	Open	Yes
8	Known Targets			Closed	Yes
9	PQ guide			Closed	No
10	PQ Presentation			Open	No
11	Valid PQ target			Closed	Yes
12	Design to target			Closed	Yes
13	Rating scales			Closed	Yes
14	PQ standards	E	The search for PQ benchmarks.	Closed	Yes
15	Personal PQ	F	The value to a person of PQ.	Open	Yes

The Questions were themed in groups to build up the PQ picture in the Company and are reproduced in full in Appendix A4.1.

4.4.4 Procedure

The survey was launched on 4th February and continued until 7th April 2014.

This was a closed, internal survey only. All responses were anonymous, with respondents only shown as a number. The survey was entirely online, and data was intended to be entered by single participants operating alone. The survey tool gave 15 questions to be posed at minimum cost and these were discussed with the Quality Manager and approved before launch. The various Themes were investigated through the survey questions with the following table of expected outcomes and what information was sought to support the research.

Table 4.3. Expected results from survey

Theme	**Type of results expected**		**Information sought**
	Descriptive	Inferred	
A - Awareness		Yes	Awareness of PQ within the population of Design Engineers.
B – Position of PQ	Yes	Yes	The design process and PQ's place therein.
C – Leadership of PQ		Yes	PQ leadership views.
D – Delivery of PQ	Yes	Yes	Relevant past experiences across other manufacturers.
E – Benchmarking PQ	Yes	Yes	Looking elsewhere other than automotive for PQ definition and examples.
F – Personal PQ views	Yes	Yes	Challenging personal views of personal product selection and purchase.

Table 4.3 preceding, details what types of results were expected from each theme. As the Quality Manager was most interested in comments and verbatims, this explains the skew of the results.

The Smart Surveys output was originally destined for use within the Design Consultancy, as well as for the thesis. The aim was to assess the views towards PQ of those Engineers who create the cars.

The questions ranged from awareness of PQ within the Company and how to find PQ information, to what people would be prepared to pay extra as a customer themselves. As all Engineers are customers of products or surveys, these were all valid requests. The questions were discussed with and validated by, the Quality team of PQ Auditors. Participation was entirely voluntary and appropriate Company protocols were followed in data collection.

4.5 Results

4.5.1 Responses overview

50 responses were received for the survey, out of a population of about 250 Design staff, and was halted at 50 as requested by the Quality Manager, who instigated the work. Only 6 females took part and the mean age was 45 years. This can be taken as a fair sample of views across the disciplines, as employees from all areas were represented. In many of the following results charts, 'Other' means an incomplete or unformatted response. All respondents were in full-time employment at the one company.

Analysis of the question types and responses is shown in Table 4.4 following. The last two questions stimulated useful qualitative data (verbatims) from the Engineers. A word-cloud is used to show these latter two, which shows what were the most used words by respondents. Word-clouds are a graphic illustration of words used in a document and shows by size of font which are the most-used words. Free-text comments were invited as shown and it can be seen that many respondents made use of this facility. In some case, extra free text areas were available, and it can be seen that some respondents again used this facility.

Qualitative as well as quantitative data was hoped for in the survey and Table 4.4 shows that even where comments were invited by the survey structure to gain more information, it was not until the last two questions that a volume of comments were received.

It is interesting that these were questions of PQ standards and personal views. The results are shown in Table 4.4 following and as pie-charts (see Appendix A4.2) where appropriate and text where better suited. A word-cloud in Fig. 4.4 on p.127 expresses the importance of words used in some of the descriptive responses.

Table 4.4. Analysis of question responses

Question no.	**Subject**	**Count of comments**	**% of respondents who commented**
1	Awareness	2	4
2	Reports	2	4
3	Reports	7	14
4	VTS	8	16
5	Where PQ	9	18
6	Responsibility	14 (invited)	28
7	PQ Target	4 (invited)	8
8	Known Targets	5	10
9	PQ guide	7 (invited)	14
10	PQ Presentation	4 (invited)	8
11	Valid PQ target	0	0
12	Design to target	0	0
13	Rating scales	8 (not invited)	16
14	PQ standards.	39 (invited)	78
15	Personal PQ	21 (invited)	42

4.5.1.1 Responses by question

The results from Questions 1 and 2 on basic awareness of a PQ gathering process within the studied Company, showed an almost even split, with 53% aware and 42% never having seen a process. The remaining 5% were ambivalent. Given the size of the Company, this was not expected, as most Engineers worked in one main room together and communication lines were thought to be open and good.

Question 3 also showed a ‘patchy’ PQ awareness, of both the subject and where to find PQ information. 57% of those surveyed had heard of PQ reports, but did not know where to find them. Only 14.3% knew of them and where to look.

71% believed that there was no process within the Company to deliver PQ into a vehicle programme. Only 3.2% answered positively to the statement “I know where they (PQ reports) are used in a programme and will explain below”.

From question 4, there is strong view that PQ is important within the VTS (Vehicle Technical Specification), with 91.8% of Engineers believing that this was the home of PQ and should be specified in some way.

Question 5 asked where in the timeline of a vehicle programme PQ targets should be set. Of the 46 valid responses to this question (a further 3 people skipped it and one spoiled their response), 71% believed that PQ should be set in the first 2 of 9 stages.

Question 6 was looking for the owner of PQ, or who should deliver PQ in a product. The vast majority, 55.3% came down in favour of a Project/Programme Chief Engineer. However, more than half also believed that individual releasing Engineers should have ownership, as shown in Fig. A4.1 in Appendix A4.3.

Questions 7 to 12 concerned targets with number 7 (Appendix 4.3, Fig. 4.2) asking “How important do you rate PQ in relation to other targets?” 75.5% rated this as very important, but only 4.1% saw it as over-riding in importance.

Question 8 considered if the Engineers were aware of any PQ targets for either system or components. Only 62.5% were aware of such matters. Clearly of interest to the Quality Manager, this showed that some work needed to be done by his team.

Question 9 enquired if the Engineers would appreciate any form of assistance to help with PQ in the form of Blueprints (e.g. Best Practice examples) or other guides. The result was clearly in favour, with over 85% agreeing that a guide would be useful.

Question 10 asked “How would you like PQ and Benchmark data presented to you?”

This reflected the earlier questions on awareness, as so few (61.7%) had seen the extant reports that they did not know how information should be presented.

Question 11 asked "Would you agree with a target for the achievement of PQ - would it help? If so, should it be a Milestone deliverable?" This showed a clear positive response, with 87.8% agreeing or strongly agreeing that it should be a Milestone deliverable.

Question 12 as shown in the Appendix, gives an over-whelming level of support for a useful PQ target with 57 positive responses. Specificity is clearly sought by Engineers(see Chapter Appendix Fig. A4.3).

An interesting result was that for Question 13 about rating scales. These showed (see Chapter Appendix Fig. A4.4) that on scales of ratings were generated a certain dissatisfaction with the then extant rating system of a simple 1 to 10 score. 62 positive responses were received.

Question 14 on PQ Standards demands further interrogation of the responses, which generated the highest rate of all questions, with 78 comments.

Question 15 inserted at the Quality Manager's insistence on Personal PQ showed a strong response of 42%.

Some of the common words used in the responses are shown in Table 4.5, following. The level of response will be used later in the building of a mental model for PQ.

Table 4.5. Question 14, word frequency

Word	**Frequency**	**% of responses**
Benchmark/benchmarking	18	23
Car	18	23
Customer/customers	12	15
PQ	11	14
Product	7	10
Experience/experiences	4	5
Best	3	4
Target	2	3
Engineers	2	3
Quality	2	3

Fig. 4.4. Word-cloud derived from question 15 (see full list in Appendix A4.6).

The word-cloud in Fig. 4.4 shows quite clearly the frequency and importance to Engineers in their personal lives of the elements of PQ. Key words showing large in the cloud are ‘price’, with ‘quality’ and ‘car’ at the centre. ‘Pay’ appears twice, as they expect and are willing to do so for good PQ according to their verbatims. ‘Engineered’ appears as a key word, as does words such as ‘premium’, ‘brand’ and ‘exceptional’.

One brand featuring in the cloud is Snap-on, the world-renowned US tool manufacturing company, who sell on quality (Snap-on 2017).

Draper, another tool company, but who have both a ‘budget’ and a superior quality product line (Draper Expert) also features (Draper 2017). Interestingly, Audi and Ford are the only car marques appearing in this analysis (as comparators).

This survey produced two categories of response, such as words discussed above, which also arise in the final two questions, but also a number of outcomes from the PQ creation process. These are logged in the next results shown in Table 4.6 following. Some of the elements from Tables 4.2 and 4.4 are repeated to enable comparison with themes in columns 2 and 3, the percentage of people who commented in column 4 (and therefore demonstrably felt strongly about issues raised) and what type of category of response this was. The two categories are 'Outcome' and 'Key words'. These will be examined later in the discussion to give some shape to creating a mental model of the results generated here. Categories of response are also shown in table 4.6 following.

Table 4.6. Survey questions, comments, themes and categories of response

Ques. no.	Theme		% respondents who commented	Category – outcome or key word
1	A	PQ Awareness amongst Engineers.	4	Outcome
2			4	Outcome
3			14	Outcome
4	B	The position of PQ in the vehicle development process.	16	Outcome
5			18	Outcome
6	C	PQ process leadership and ownership.	28	Outcome
7	D	The delivery of PQ.	8	Outcome
8			10	Outcome
9			14	Outcome
10			8	Outcome
11			0	Outcome
12			0	Outcome
13			16	Outcome
14	E	The search for PQ benchmarks.	78	Key words
15	F	The value to a person of PQ.	42	Outcome & key words

Table 4.6 shows that there are mostly outcomes from this survey, things that respondents thought should happen or be in place. The research questions, key words, themes and any links will now be examined. The relationship between the main thesis Research Questions, the Survey Themes and the results of the word count are shown below in Fig. 4.5.

This formed the basis for the use of Template Analysis, a form of Thematic analysis which is useful for understanding qualitative research (Brooks et al. 2015). In this case, the following process was followed:

1. Verbatims from question 14 (Should we place less reliance upon benchmarking cars and look elsewhere?) were analysed and key words written on sticky notes.
2. The notes were arranged under *a priori* headings using the Research Questions.
3. These groupings were compared to the Survey Themes already presented and the word count process.
4. The result of the above is shown in Fig. 4.5 following.

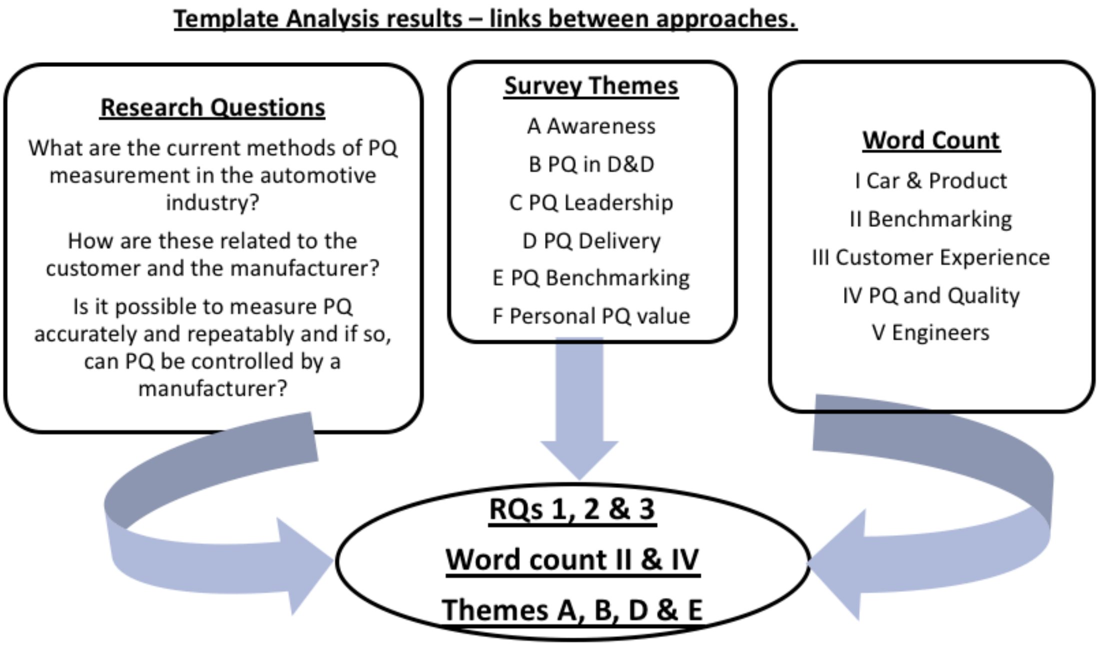


Fig. 4.5. The relationship between the Research Questions, the Survey Themes and the results of the word count as part of the Template Analysis.

The relationship diagram above shows that all the Research Questions were related to the Themes and via the word count.

Word count items I (Car and Product) and IV (PQ and Quality) were linked to all three headings and Themes A (Awareness), B (PQ in D&D [Design and Development]) D (PQ Delivery) and E (PQ Benchmarking) were also related.

The headings for Template Analysis are shown below in Table 4.6. These are verbatims used by the respondents. They are again grouped under the *a priori* headings from the Research Questions.

Template for Question 14 - version 1b		
1) Current scoring and Benchmarking	2) Relationship to Customer and Manufacturing	3) New PQ measure
1.1 Current scoring	2.1 Customer	3.1 Materials
1.1.1 Market trends	2.1.1 Customer influences	3.2 Texture
1.1.2 Innovate	2.1.2 Customer buying/use experiences	3.3 Colour
1.1.3 Catch-up	2.1.3 Customer service	3.4 Look at any product
	2.1.4 Customer perception	3.5 User Interface
1.2 Benchmarking	2.1.5 Customer focused targets	3.6 Sub-systems
1.2.1 World Leaders	2.1.6 What do customers want?	3.7 Tailoring PQ
1.2.2 Standards	2.1.7 Customer behaviour	3.8 PQ - Media, Dealership, test, Finance, Life-style
1.2.3 Competition	2.1.8 User Interface	3.9 (Other) Consumer products
1.2.4 Competitor Benchmarking	2.1.9 Customers are not generally Automotive Engineers	3.10 Demographics
1.2.5 Benchmarking strategy		3.11 PQ subjective, therefore changes
1.2.6 Benchmarking looks backwards	2.2 Manufacturing	3.12 Home hi-fi
1.2.7 Benchmarking specifics or systems	2.2.1 (Top) Suppliers	3.13 Understand PQ (the Business)
	2.2.2 Aging design	3.14 Limit ambitions?
1.3 Price range	2.2.3 Engineers and detail	3.15 Inspiration
	2.2.4 Deliver PQ	3.16 Communication
		3.17 Project where you want to be
		3.18 Social media

Table 4.7. Template for Question 14

4.5.2 Inferential data analysis

SPSS software was employed to look for some correlation between responses.
The almost even split between Engineers who said they were "aware" of PQ and those who did not, from Question 1 was used as dependent variables, similar to gender in many other surveys.
Gender was so skewed towards males that this was not used as a variable here.
The tables and graphs from Chi-squared analysis, looking for a relationship between factors, that follow in the chapter Appendix A4.3, show none between the Awareness state and the independent variables from Questions 6, 10 and 13 (Responsibility for PQ, PQ Presentation and PQ scoring).
These three questions were selected to represent three of the four survey themes shown in Fig. 4.5. The Chi-squared data results are in Appendix A4.3, p. xlviii and show that the probability of a link in each of the three questions is much greater than 0.05 in all cases, with the smallest value being 0.301. Thus, there is no link.

However, the statistics showed that with the Chi-squared test, all options were run, and the interpretation is that the Chi-squared doesn't show any evidence for a relationship between the Awareness group and the question responses. The main output from the Chi-squared test showing this is in the "Pearson Chi-Square" row, and the "Asymptotic Significance (2-sided)" column. This is the "p-value", its simplest interpretation being the probability:

If $p > 0.05$, there is no evidence for an association between awareness group and question response.

if $p < 0.05$, there is significant evidence for an association between awareness group and question response where the graphs show which direction that's in, i.e. which group answered which way.

As the Chi-squared test was insufficient to demonstrate a relationship, a non-parametric test was then employed, the Mann-Whitney U test (also known as the Wilcoxon-Mann-Whitney test). This considers rank and looks for differences between the groups on a dependent variable. The results are shown in Appendices 4.4.

There has to be acceptance of a null hypothesis, i.e. that there is no relationship between those Engineers who are or are not aware of PQ and the three considered aspects of PQ Leadership, Benchmarking for PQ and PQ Scoring.

The Mann-Whitney U tests are to establish if there were disparities in each of the three fundamental questions on PQ Leadership, Benchmarking data and PQ Scoring. This test is suitable for non-parametric data. A visual assessment of the scores was made (see Chapter Appendix A4.10) and although the distributions looked similar, the test showed no statistically significant difference between those who were aware of the PQ process and those who reported that they were not.

Uvalues range from 240.5 to 273.5,

z values from -.99 to -1.041 and

the asymptotic probability p-value was 0.322 to 0.810.

So therefore, the null hypothesis of no relationship has to be accepted.

4.6 Discussion

This first survey was conducted to support the thesis research questions, one of which is to find a new way of measuring PQ. The survey just concentrated upon the creators of PQ, the Engineers and looked at their views of PQ, their own effect on it and how it is delivered through their daily work. Safety was not an issue of special interest to the Quality team at this point in relation to PQ. It was discussed with the in-house Safety and Conformance team and as it was considered a Kano *Basic* factor, for instance customers *expected* a new car to feature 'Isofix' points to which child seats could be attached and a top-tether location for the same. Engineers were at liberty to mention safety in their responses, but few chose to do so.

The themes followed in the survey looked to develop logical steps from how aware they were of the subject through ownership of PQ, delivery of the same and a question relating to benchmarking, finally asking for a more general, yet deeply personal view of PQ in their own purchasing experiences. The question types and themes were guided by the Quality Manager.

The responses to questions 1 to 3 about PQ awareness showed that the Engineers believed that they certainly should be able to affect PQ but did not feel equipped to do so.

This indicated a need to communicate better by the Quality function. The Quality Department believed it was clear PQ needed to be brought more to the front of Engineers' considerations.

Free-text comments were invited and some of the verbatims were illuminating, such as:

> "I think PQ should be more organically connected with development process rather than documented drily."
>
> "For a given program and particularly a given brand, the PQ target should be inherent in deciding budget."
>
> "Touch, feel, efforts, etc. - massively important for customer perception and it can cost little or nothing with good engineering"

The preceding verbatims demonstrate in the first example that mere documentation was felt to be insufficient, implying that it was inherent in what Engineers did. The second two comments are related to budgets and finance but looking at finance from two different angles. One suggests catering for PQ within a budget (implying good PQ costs money) and the other designing PQ *into* a product. The third comment backs up the first one and gave further impetus to the Quality Department's PQ programme and to this thesis.

Question 4, looking at the role of PQ within the VTS showed a very strong opinion that the 'home' of PQ was in such a specification, that PQ should be included in the product content and as such it could be included in the project budget. So here we had strong views of Engineers wanting to affect PQ and have a place where they could find PQ specifications.

For question 5, where PQ targets should be set in a product programme, the responses match research at Volvo Cars in Sweden and what the same researchers found when visiting Japanese manufacturers to compare Japanese and Swedish attitudes to PQ (Bergsjö 2011; Wagersten 2013).

As to who should deliver PQ in a project, in question 6, although the majority plumbed for the Programme Chief Engineer (a very strong point in Japanese companies), the verbatims used the word "everyone" or "a team effort", recognising input from all. This result appealed to the Quality team, who were trying to engage more people in the creation and development of PQ across projects. The impact upon the thesis research is that this upheld earlier studies by the team at Volvo Cars and established the base-line for further data collection in surveys 2 and 3 (Bergsjö 2011). The hypotheses were also validated, as discussed in section 5.1 following.

Questions 7 to 12 on targets and guide for PQ again showed that Engineers, who are used to working to targets wanted PQ to be one of the ones that they worked to; not the over-riding one, but very important. Having a target for PQ and a place in the VTS would certainly mean PQ being captured within a project budget, an all-important consideration.

Question 13 asked about rating scales for PQ and although the respondents were very used to using the simplistic 1 to 10 rating scales, 16% of them chose to comment, even though these were not specifically invited by the survey, indicating a strength of feeling for this issue. This backs up one of the central tenets for this dissertation, whereby something more than just a quantitative measure of PQ is sought, something that takes into account fuzzy or imprecise areas of response.

Question 14 invited comments on PQ standards and as such scored the highest response rate of comments at 39 which represented 78% of the respondents. This clearly hit an intrinsic need for Engineers to know what standards, be they legal, performance, dimensional or anything else to which they must adhere in their work.

Question 15 was added by the Quality Manager, who thought that a more personal view of PQ would create a level of response, in which he was correct, with 21 commenting, 42% of respondents. The manager thought that giving people chance to voice more personal views, not constrained by the automotive world would generate some good ideas on PQ definition.

The word-cloud in Fig. 4.4 shows some of the words used in replying to this question, with “price” and “pay” standing out front and centre as considerations where PQ was concerned.

Unsurprisingly for Engineers, some other car marques with good PQ such as Audi, and - perhaps less expected - Ford, appeared. Brand, already mentioned as crucial in Chapter 1, also shows in the cloud. Again, not unusually for this group of people, two tool manufacturers appeared; Snap-on and Draper. Clearly tools are core to an Engineer’s private as well as working life and hand-tools are something to which they can relate. Two other products, which must appeal to the Engineer’s idea of PQ are ‘perfumes’ and Hi-fi (hi-fidelity audio equipment).

Looking at reactions as shown in Table 4.6, this did show that the questions produced two responses categories: an outcome (that helps describe PQ) and a set of key words (that again help describe PQ). This was not recognised when setting the questions, but clearly arose upon analysing replies. Most replies were in the ‘outcome’ category; less so in ‘key-words’ and these are considered in the mental model presented later.

It is unclear why question 14 produced so many comments and resulting key words, but these are summarised in Figs. 4.6 and 4.7 following in section 4.5.3.

The template analysis that was shown in section 4.1 demonstrates that the chapter research questions set were linked by the themes covered by the 15 questions and these were related to the resulting replies via the word count. The latter showed five groups of words, Car and Product, Benchmarking, Customer Experience, PQ & Quality and Engineers. Out of all this, as shown in Fig. 4.5, the three research questions, the word counts for Benchmarking and PQ & Quality and most of the Themes were inter-related. Further evidence of this is given in Table 4.7, which groups the most-used words under the Research Question headings and again finds correlation. What stands out from this table is the respondent's search for a better or new PQ measure, a principal driver for this thesis research, garnering 18 replies.

Using the Template Analysis tool, there was a clear relationship between the Research Questions, the Survey themes and the word count used to analyse the verbatims from respondents, as shown in Fig. 4.5.

However, the statistics analysis did not present much new learning, with no evidence shown for an association between the aware/not aware groups, used as the dependent variable and selected questions to represent the themes. The use of Chi-squared tests and Mann-Whitney checks provided no relationship links. A difference was expected, but nothing was found. This could be as a result of using the aware/not aware as the dependent variable, in the absence of something more usual like gender.

So, what does this all mean? If we look back to Chapters 1 and 2, we were looking for a new assessment or measure of PQ as described in the Introduction. What has come out of this survey is a strong belief among the very creators of PQ – the Engineers – that it is a vital ingredient in any vehicle project and one that should be there from the beginning.

It should also be led by a responsible person, such as a Programme Manager or Chief Engineer, to lend some authority. Chapter 2 looked at UX, design and emotion as well as the human senses as part of the definition of PQ, with a strong slant towards attributes.

These are all familiar to Engineers, although not always as formally discussed issues or parameters by which their output is measured. They will be more familiar with issues such as panel gaps and surfacing, also introduced in Chapter 1, which are more easily measured and reported upon.

What was expected in this survey was a greater awareness level amongst the particular Engineer population. The Quality Manager was somewhat disheartened that the Quality team's promotion of PQ values and its importance to a successful vehicle had not been recognised at that time, so was looking for the survey to give PQ some greater recognition. It did so merely by debate among participants during and after their taking part in the survey.

4.6.1 Survey Critique

As a critique of the research may be useful here, it must be recorded that this survey was the first of its kind in the Company and no real precedent existed to follow. The driver for the work was a keen interest for the Quality Manager in the UK arm of the Company (and their superior in the parent operation in another country), to know more about PQ.

As has been established, PQ is about intangibles, such as emotions and individual taste, so the search for more Engineering or science was ongoing.

The survey was restricted as a pilot study and only allowed 15 questions, which was considered to be a threshold for participants' patience in a world full of surveys and questionnaires. That the work was undertaken in Company time did not exclude the occasional frivolous or deliberately useless response but did mean a good sample size of 20% of the team of 250 Engineers. The questions selected for further statistical analysis were those shown by responses to be worthy of such treatment and those which generated useful verbatims or qualitative data.

The use of two tests, Chi-squared (looking for associations) and Mann-Whitney (seeking differences) was perhaps flawed in using the factor of awareness/not aware as the dependent variables. This was used as there was no simple gender split or other variable. ANOVA could have been employed to compare the populations.

4.6.2 Analysis of survey questions (SQ's)

SQ1 Do Engineers create PQ and are they aware of doing so?

SQ2 Is there a Leader, or Owner of PQ in the product creation process?

SQ3 Do Engineers have a view on how to manage and deliver PQ into products?

The survey questions were answered through this data collection exercise.

For SQ1, it was clear that there were some Engineers who had strong views on PQ and knew that they had a huge influence over its creation, yet there were some, who from their verbatims had not considered this before. Over 70% of respondents suggested that PQ is set at the earliest stages of a product development cycle, where Engineers are first engaged in taking the sketches, models and schemes developed by the Styling Studio into hard lines and forms.

SQ2 was answered for instance, in response to Question 6 on responsibility for leading PQ, respondent 14948484 said "Design, Project Manager, Marketing, COC - Managed by attribute owner", so this person saw a spread of ownership, including themselves. Another participant, number 16826312 suggested "Needs to be led from the very top of the company". Several others replied "Everyone", or words implying a collective responsibility.

SQ3 was really discussed in the latter stages of the survey and where delivery targets were concerned, the majority of Engineers had strong views on these. Question 7 asked where these were and 79.6% said that PQ was important or very important, yet with 66% not knowing where these targets were to be found. When asked if they would welcome a 'Blueprint' or guide to PQ, 85.7% were positively in favour.

4.6.3 Building a mental model for the Engineer's survey results

Mental Models were introduced in Chapter 1 and are a useful way of showing thought processes diagrammatically. In order to build up to such a model, there follows Fig. 4.6, which is a summary of issues arising in this chapter. There then follows the mental model in Fig. 4.7 for this experimental survey, which takes the simple summary and builds it up to show relationships between themes and the size of the response to the questions. The thesis will see further models created for the other two experiments/surveys and will summarise the output from each study carried out.

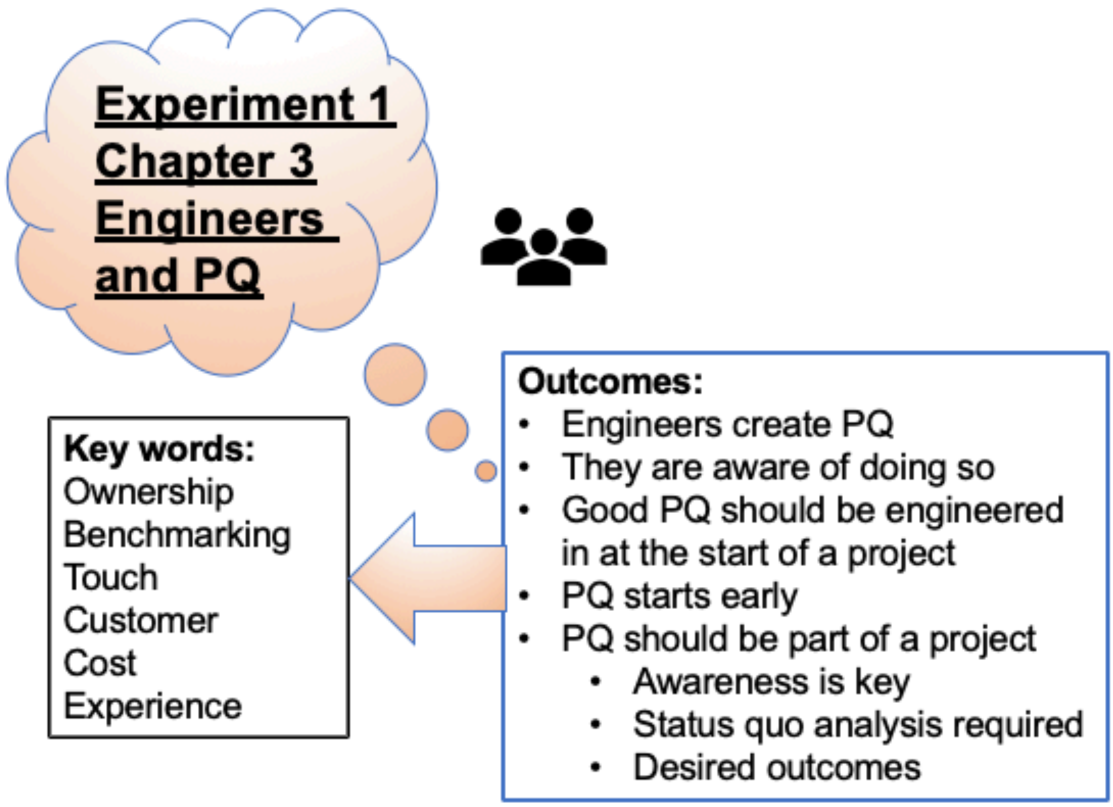


Fig. 4.6. Summary of key words and outcomes for the survey results

The model in Fig. 4.7 shows the central messages and findings from this survey on engineers.

From the model, as an engineer, it was expected that cost would be a key word, with ownership/customer and the experience also intrinsic to what engineers do in their creation of product.

Touch is an element that most engineers are fortunate to be able to experience for themselves in a final, tangible product, so they have a clear relationship with that which they create. Finally, benchmarking is an issue which in this company and many others is a way of doing business by looking at competitor products and standards to ensure that engineers in particular are up to date with current thinking.

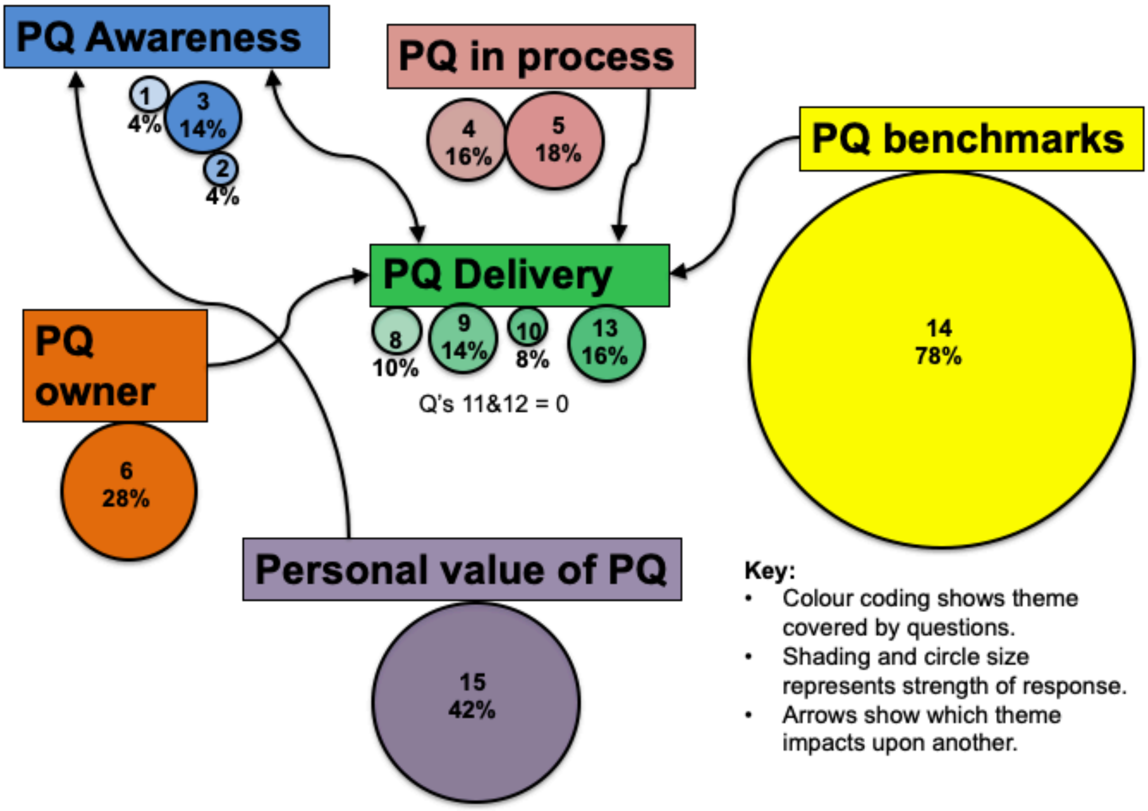


Fig. 4.7. Mental model for the survey findings across each theme.

The impact of one element on another is marked by arrows. These are experientially derived.

Fig. 4.7 takes the summary from Fig. 4.6, overlays the themes picked out in the study and adds in the strength of response shown in Table 4.4 to each question, shown by the area of the coloured disc.

Percentage of response is shown below each question number. Some questions such as 11 and 12 had a nil response, so are not shown as discs.

4.7 Conclusions

As can be seen, the research questions and others were addressed:

Are Engineers aware of PQ and where it was created?

Who was responsible for PQ?

When and how it was delivered within a vehicle programme?

How were benchmarks of PQ arrived at?

It was found that engineers do indeed create PQ and are aware of doing so. Again, a few verbatims from the survey proved illuminating, such as:

- "Good PQ should be engineered in for zero cost." (Question 15)
- "It should be baked into the process from concept to production….." (Question 5)
- "Everyone should play a part, sooner rather than later." (Question 6)

This and other evidence found in the survey means that agreement is reached with previous research in Volvo Cars, that engineers certainly do create PQ and it needs to start being managed very early on in a vehicle programme(Wagersten 2013: 61).

A search for a relationship between selected survey questions 6, 10 and 13 via a statistical method showed neither a real difference, nor a real connection.

These 3 questions represented 3 of the 6 themes covered by the survey (see Tables 4.2 and 3).

It could therefore be argued that more work could be done to understand these others in future research. It could be suggested that a different set of only 3 themes were necessary as following in Table 4.8. However, sufficient information has been gained for the analysis covered thus far that it is unlikely that more could be gained from either of these approaches.

Once completed, the thesis was assessed by the originator of the research and the efficacy of this approach (in his view) will be presented as a summary of chapters 4, 5 and 6 in the Discussion chapter 7.

4.7.1 Gap analysis

The three ‘Combined’ themes following in Table 4.8 are two of the three common themes in much gap analysis type of questions, i.e. “Where are we now?” and “Where do we want to be?” All of this shows that a better definition of PQ and an improved method of measuring the same is required.

Table 4.8. Possibly reduced or different themes

Original theme in this research	**Questions**	**Combined or revised theme**	**Questions**
A – Awareness of PQ	1 to 3	Awareness	1 to 3
B – Position of PQ	4 & 5	Status Quo analysis – delivery of PQ	4 to 13
C – Leadership of PQ	6		
D – Delivery of PQ	7 to 13		
E – Benchmarking for PQ	14	Desired outcomes	14 & 15
F – Personal PQ	15		

As the Company was a typical manufacturing or results driven operation, the emphasis was on delivery in terms of the amount of questions asked, so it could be viewed that as this took up nearly half the questions, it was a biased view. However, it was very much a commercially driven exercise with an over-arching plan for the whole thesis to be so targeted in order to be useful to the Company, who initially sponsored the research.

Since parting with the original sponsor, subsequent employment in a rival OEM has seen a similar accent on PQ delivery. This will be examined further in Chapter 5 and also in 6.

4.7.2 Confirmatory Analysis

An explanatory or confirmatory factorial analysis was considered useful at this point, to determine if there was any overlap between the themes. For instance, we could assume that Theme A (PQ Awareness amongst Engineers) is included in all the other themes, as they all cover PQ.

Confirmatory analysis tests whether the measures of a construct are consistent with the researcher's understanding of the construct's nature. Such analysis puts the findings and arguments to trial. testing the hypothesis or hypotheses, using regression and variance analysis.

In this study, PQ Awareness was clearly included in all the other themes, as they all cover PQ. confirmatory analysis may help determine if there is any overlap between the themes.

Confirmatory Analysis looks to take many factors, assess any similarities in the data for each and reduce the factors in number. In this study, we had 15 factors and reduced them down to six themes. The preceding section showed this further reduced to just three factors.

Reviewing the two hypotheses stated at the head of the chapter, (p.108) it was posited that:

- Engineers create PQ
- PQ must be managed

So, do the results from the study support these statements?

Hypothesis 1 is supported by questions 1, 2 and 3 (Theme A) and questions 7 to 13 (Theme D).
Hypothesis 2 is supported by questions 1, 2 and 3 (Theme A) and 6 (Theme C).

These will be presented in Fig. 4.8 as a factor analysis tree.

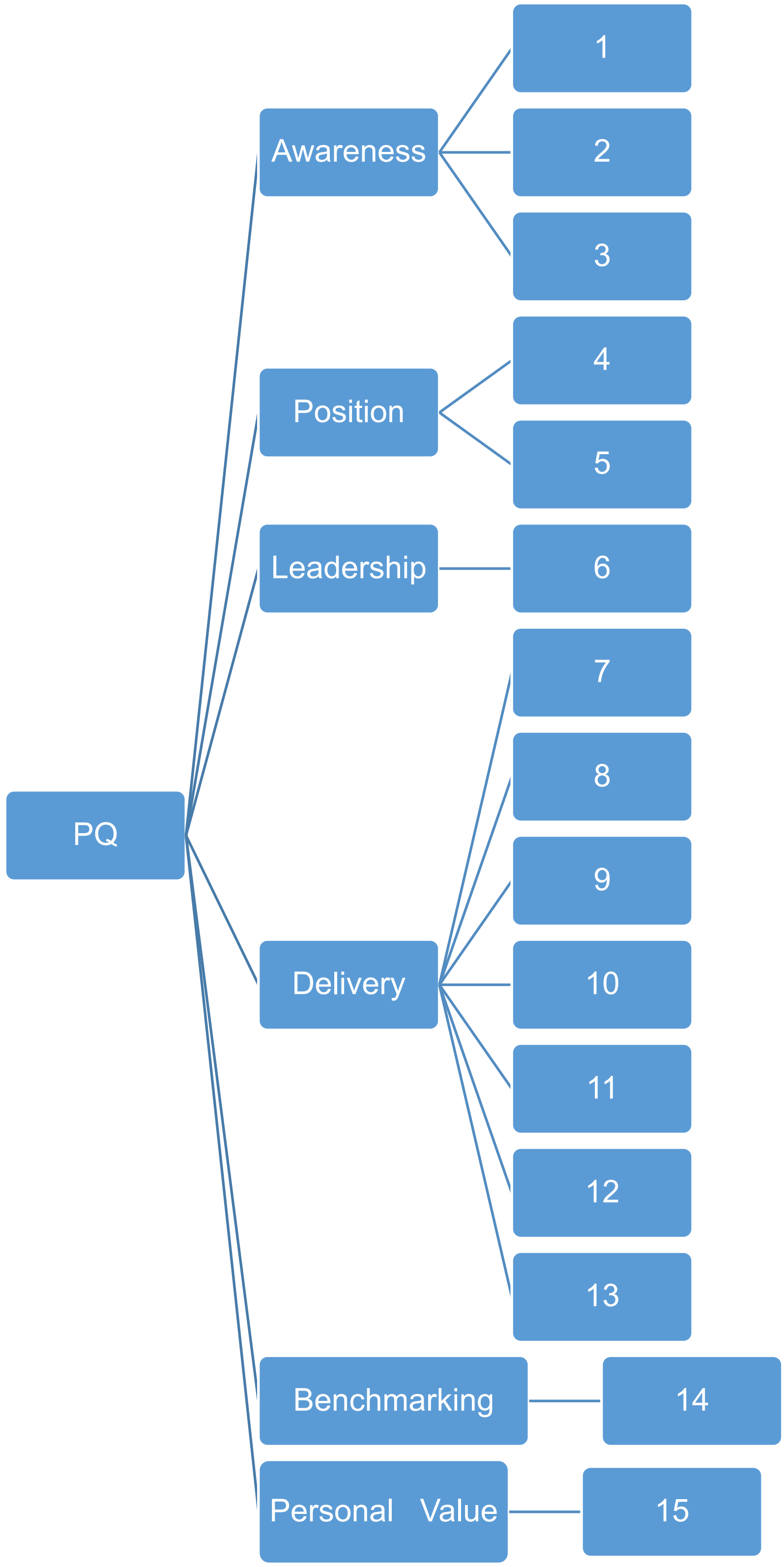


Fig. 4.8 Factor Analysis tree showing themes and questions

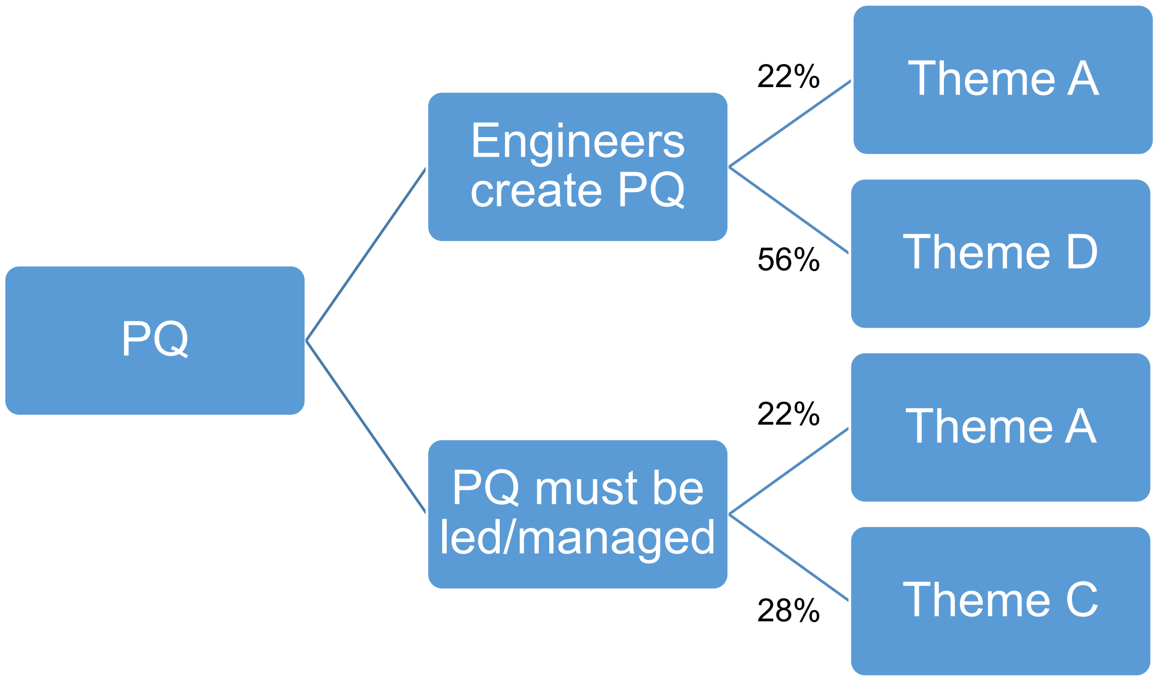


Fig. 4.9 Factor analysis tree relating hypotheses to themes.

Reducing the tree in Fig. 4.8 relating the hypotheses to the themes is shown Fig. 4.9 above, the figures are taken from Table 4.6 and the percentage of respondents who commented on the themes. This gives some sort of weighting to each one. Adding the scores for A and D and A and C gives 78% and 50% for hypothesis 1 and 2 respectively. These are not unreasonable scores and would therefore give credence to the original postulations.

4.7.3 Polychoric factor analysis

Using the data collected from the survey it would be expedient to examine the relationship between the different items of the survey, in order to assess any commonality or shared factors. In order to perform this an exploratory factor analysis would be the standard test to be performed. however, there are several issues with this approach due to the data collected within the survey. A factor analysis requires continuous data, but the data gathered within the survey was ordinal - and the majority of items required a binary response ('yes' or 'no'). Further to this the low participant sample that completed the survey presents another limitation. An exploratory factor analysis is thought to be able to address low sample sizes - but the nature of the ordinal data does not satisfy the requirements for a traditional factor analysis. However, there are other approaches to factor analysis that can be used that will allow us to consider the relationship seen within this sort of data set - a polychoric factor analysis. This takes into account the presence of ordinal data and generates a correlation matrix across all variables. Holgado et al (2010) outline the need for factor analysis techniques that account for ordinal (mostly Likert scale) data capture, and further discuss the means by which variance between variables can be analysed by adopting a polychoric correlation.

Based on the data set derived from the current survey we are presented with limitations in terms of both sample size and data type, but a polychoric correlation would provide a method of exploratory factor analysis to allow us to calculate the relationship between different variables through the production of a variance-covariance matrix.

There are not many statistical packages available that provide this type of analysis, with SPSS being a good example. It is possible to run the statistical test on other software but would require significant training on its use (e.g. R for statistical computing). During investigating a means by which to perform this analysis it was found possible to use an R plug-in extension that would allow for the running of this test in SPSS, but the complexity of coding the syntax was significant.

Therefore, a different software solution was sought. FACTOR[1] is a free software programme that allows the entry of ordinal data in order for polychoric factor analysis. This software was installed and the data sheet from the survey was transformed into a .dat file in order for it to be processed by this statistical package. Factor requires a number of fields to be completed before running the statistical test, so the number of participants was entered (N=49) and the number of available measured variables/items was also entered (59). From this a polychoric factor analysis was selected (using principal components analysis). Missing values were accounted for and an option of rotation was available - so a traditional normalised varimax rotation was used. Following a number of stages being completed (e.g. transforming data set, constructing model type) the analysis was computed in FACTOR. For a detailed explanation of the computation applied and the smoothing algorithm, please refer to Lorenzo-Seva & Ferrando (2013). This resulted in an output file (see Appendix) that provides an observation plot for each variable and following these a correlation matrix (see Appendix A4.5).

From the matrix, any relationships greater than 0.7 in the upper half were considered significant and the following table 4.9 shows these against the Themes developed in this Chapter.

The table was created by:

1. Looking across the matrix and recording what factor of the 59 (representing each survey question) scored above 0.7 (significant)
2. Relating the factor number 1 to 59 to the original question.
3. Recording how many occurrences existed of greater than or equal to 0.7
4. Relating the question to the original subject.
5. Relating these to the Themes outlined in the chapter.
6. The numbers in brackets are the sums of the occurrences.

Table 4.9 Assessment of matrix results for polychoric factor analysis

Factor	Question number	Occurrence	Subject	Theme
11	3.2	1	PQ reports (1)	Awareness (1)
17	5.3	2	Where PQ fits (14)	Position of PQ (14)
20	5.6	4		
21	5.7	4		
23	5.9	4		
25	6.1	1	Responsibility (2)	PQ Leadership (2)
29	6.5	1		
30	7.1	2	PQ target (2)	Delivery of PQ (18)
38	9.2	1	PQ Guide (4)	
40	9.4	1		
41	9.5	2		
42	10.1	1	Delivery of PQ (14)	
43	10.2	1		
45	10.4	2		
46	10.5	1		
55	13.3	2	Original scoring regime (7)	
56	13.4	2		
59	13.7	3		

Commentary on Table 4.9

The analysis shows that the strongest relationships between factors exist within the "Delivery of PQ" theme (Theme D in the chapter - see Table 4.6), scoring 18 in the table above.

"The position of PQ" (within the vehicle development process) theme (Theme B in the chapter), shows as the next strongest set of relationships with 14 scored.

"PQ Leadership" (Theme C) and "PQ Awareness" (Theme A) came some way behind these two, scoring merely 2 and 1.

The original hypotheses for this chapter were that:-

- Engineers create PQ
- PQ must be managed and controlled during its creation

The results above support the first hypothesis through Theme D. The second hypothesis did not garner such support in terms of Theme C, but Theme B is directly associated with where PQ sits within the development cycle and therefore, its creation.

This drove the researcher into taking advantage of a change of employer and therefore a change in PQ emphasis from a manufacturer's point of view. As PQ delivery and position were such strong scorers, these were pursued in the next Chapter on the manufacturer and PQ attributes. It was determined that how PQ was delivered would be examined along with where the emphasis on PQ was placed within the development process, by looking at the attributes that were important to the new employer/manufacturer.

4.7.4 Next steps

Having examined the role of Engineers in the creation of PQ and been satisfied that the research questions set were answered, it is a logical step to consider the customers of these Engineers who receive use and often purchase the products that they create.

Without such customers, there would be nothing for the Engineers to create, so the two groups are mutually dependent. Whereas the Engineers could be accessed directly through a place of work at the invitation of the management of the Company where they were employed, the real paying customer had to be approached in a different manner, as members of the General Public.

Before this is done, the role of the manufacturer as manipulators or custodians of PQ needs to be considered. The Engineers create the PQ and work within a Company framework, so it is a logical step to examine that framework for PQ.

The methodology will again be a survey on attributes, to generate quantitative and qualitative data, analysed via ISM. The chapter format will follow the layout of this one, to enable comparisons, links and a similar flow of argument, so it is time to move on to the management of PQ. This is the responsibility of the OEM, the vehicle manufacturer.

“Customers are not looking for products, they are buying great experiences. Improving the quality perception of cars is an effective way of turning a car into an enjoyable experience”.

(BlueThink 2019)

Chapter 5 - Manufacturer's survey and PQ attributes

5.1 Chapter hypotheses

- It should be possible to create a single list of PQ attributes.
- Manufacturers are the custodians and developers of PQ.
- Manufacturers use their PQ to sell product.

5.1.1 The linking thread of Kano

Further to the discourse in Chapters/sections 1.6, 2, 3.1 and 4.1, Kano's model was shown to be key to the work of Engineers in creating PQ. As this chapter is considering the next stage in the PQ creation toPQ consumption process, the role of the OEM can also be shown to be described by the Kano model.

The OEM itself has a duty and desire to control and manage PQ in order to make their products more attractive to the customer. Similar to the Engineers using the model to look at the validity of design details and specifications, the OEM create the master vehicle feature list (from which the Engineers work) to see if these high-level features are in the customer 'Delighter' category or now accepted basic ones. The Kano model is well suited to be considered at high levels of operation or also at the deeper detail level and is three-dimensional in this respect.

We shall examine attributes closely in this chapter and the role of these in describing and defining PQ according to an OEM. Features or attributes are so key to the Kano thinking and therefore we will continue to link the thesis thread to this work.

5.2 Background

As discussed in the previous chapter, PQ is created by the Design Engineers. However, this is just one aspect of the PQ model, with Engineers being one of several key stakeholders in the process of creating and experiencing PQ. Apart from the customer, the actual manufacturers also play an important role in acting as stakeholders; both in promoting and exploiting PQ. Drawing upon extensive experience from within the industry and the ability to access some of the people who take the created PQ and use it, this second study will examine attribute lists from three sources which purport to represent PQ and see how these are accepted or otherwise by an OEM. This evaluation will be outlined later, as it is the PQ attributes or product characteristics, with which a manufacturer imbues their offering to the customer (Hossoy et al. 2004).

Much of the PQ literature mentions the subject of 'Attributes'. Indeed, attributes have been discussed more in depth in this thesis (earlier in Chapter 2.2 and Appendix A5.1). One significant recent piece of literature that reviewed the subject of attributes was presented at D&E 2016 (Design and Emotion Conference 2016, Amsterdam), entitled "Do we really know which vehicle attributes are important for customers?" (Kukova 2016). This work coalesced what was currently presented within the PQ literature, in that there exists no single, universal list of attributes. There endures therefore, a gap in the research for an agreed, universal set of attributes. This is unlikely to ever come about as all Automotive OEMs strive to create something unique of their own. Such distinctiveness arises from their own views on attributes that are applicable in creating such uniqueness, which may contribute to their own Brand.

It would therefore be of value to examine different attribute lists to see whether there is a shared category and classification of attributes that can be presented as a single unified set. This would therefore allow us to understand the nature of shared characteristics across different attribute lists that purport to be representative of PQ.

We have seen in the previous chapter where Engineers create PQ, so this chapter will address those people charged with defining and refining vehicle attributes via a study of an OEM's PQ Management team; those who are responsible for PQ administration and deployment in a manufacturer. How PQ is defined and articulated within a Company is a fundamental question, so this is why the next study was presented to an OEM's PQ team. Three lists of attributes (one from the commercial world, one from academic study and one from an OEM, see later), were presented to them and these were discussed. They then chose between themselves the one which best described PQ. The team then weighed up the attributes against each other as a pairwise comparison via ISM. So, through this study we will look at the language used by the OEM's as the custodians of PQ.

5.2.1 Pointers from attributes research.

Of the over 330 pieces of literature on this topic (see Chapter 3), 32 papers made mention of the subject of attributes and some made them a core issue to research (Kukova 2016). A table of the 32 papers (along with an associated critique) can be found in Appendix A5.1. The table shows the Perspective, Metrics and PQ-related subject tackled in the research, where Perspective is classed as User (Customer), Engineering or a Mix of the two. Metrics are shown as Subjective or Objective and Qualitative or Quantitative. Related subjects are also those of concern to this thesis on PQ, i.e. Design and Emotion, the Senses, Craftsmanship and Culture. These different aspects are charted following in Fig. 5.1.

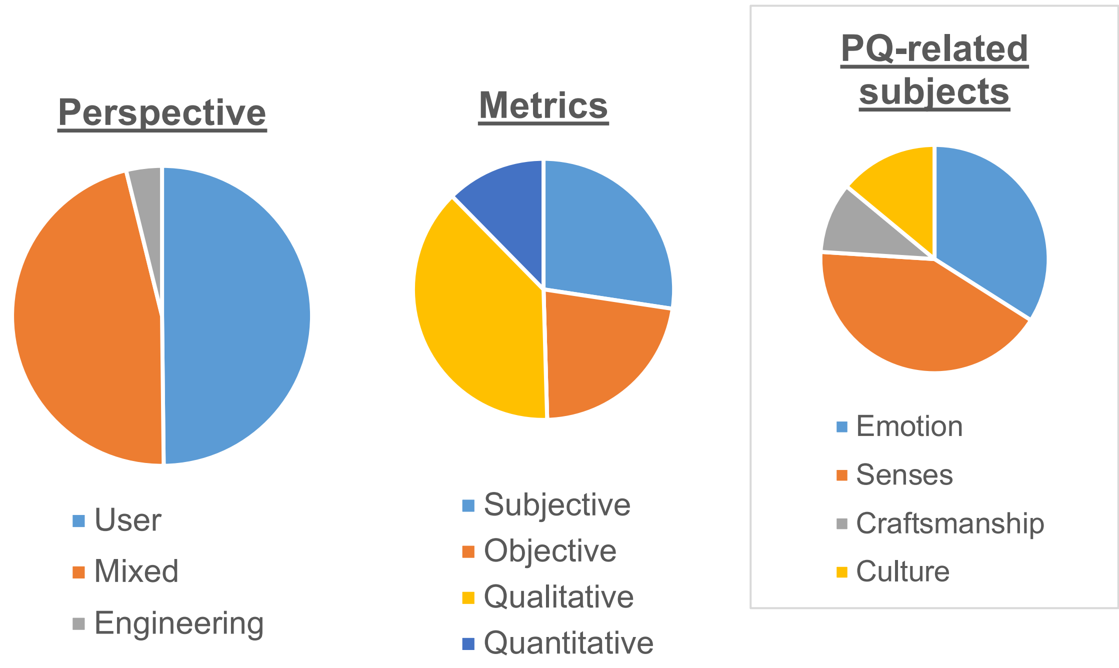


Fig. 5.1. Attributes classed by Perspective, Metrics and PQ-related subjects

It is clear from the charts, which are a simple tally of works encountered researching PQ, that the User/Customer is a primary focus, with subjectivity of quality at the core. Emotion is shown to be an important subject for discourse, as are the senses that we use to assess PQ.

Clearly from the simple tally in Fig. 5.1,there certainly is value, judging by their frequency of use, in exploring attributes and how a manufacturer or OEM develops and manages their own unique list of such factors. This chapter will analyse one such OEM to survey how they do this in order to sell their product. These 32 sources (so about 10% of the total sources for this thesis) mentioned attributes at least once, in many cases multiple times. It could be argued that 10% is a low figure, but of the papers that do exist, attributes are discussed in great detail and are a real focus of any OEM.

The rest of this Chapter will consider the role of the manufacturers as custodians and managers of PQ by proposing three perspectives on attributes, found in Table 5.1, section 5.2.3, and focus on the three sectors of:

- Academia – researching with no commercial bias (see list ***K***)
- Commerce – i.e. selling PQ information for profit (see list ***N***)
- Automotive industry – i.e. creating and managing PQ (see list ***M***)

Each of the sectors approach the attributes and perception of PQ differently, as will be discussed in the following sections.

Commercial PQ interests range from powerful media sources, such as Top Gear on the BBC and J D Power, possibly the most influential sellers of PQ data. Their brief is simply to sell their 'product', be it a franchised TV programme, a paper or on-line magazine or a car-choosing aid. This thesis is not a commercial study but has to accept that these forces have a role in PQ promotion, debate and possibly standard-setting. So, it is relevant to include a list from commerce. A commercial list was vital, as a basic tenet of this and other PQ research is that PQ is a decisive ingredient in the Purchasing process discussed in Chapter 2.6 and Fig. 2.14 (Turley, Williams and Tennant 2006). Academia clearly has no commercial angle, but involves a search for the truth and enlightenment, so can assess the issue with unbiased eyes. We are conducting an academic study and should review other unbiased assessments, hence their inclusion.

The manufacturers have their very survival at heart. They stand or fall on a heady mix of design, brand, fashion and quality. As this thesis was initially driven by an engineering consultancy and automotive manufacturing desire to know more about PQ, then manufacturers need to be included in the study.

5.2.2. Why the manufacturers?

Manufacturers employ the Engineers questioned in the first survey where PQ is created, but unless the OEM has a plan to manage and deploy PQ, then it could be directionless and off-target for that manufacturer. PQ needs to fit in to a plan that suits that marque; a budget brand would be foolish to aim for the same PQ as a luxury or premium product. For example, millions are spent on trying to keep vehicles quiet, but the standard for a £100,000 car will be different to a £10,000 offering.

There is little agreement across industry or commerce as to what constitutes PQ attributes. Some definitions are shown in Appendix A5.2 and examples of attribute listings are shown in Appendix A5.3. Each OEM uses their own attribute listings to create and re-inforce their Brand image, as shown with BMW in Chapter 1.6.

There have been some interesting but contrasting academic studies on these issues (Garvin, Aaker and Zeithaml, cited in Stylidis, Wickman and Söderberg 2015; Kukova 2016).

When we examine the lists of attributes generated by the manufacturers, such as those shown in Appendix A5.3, we see a diverse range of words being used. These words are gathered from those manufacturers who target customers in the Western hemisphere, and a difference can be seen when we examine similar lists from other countries (see section on senses and odour in Chapter 2 and more detail in Appendix A2.1).

5.2.3 Academic and commercial views on attributes

The generation of these attribute lists is therefore a critical component of how we arrive at PQ evaluation and definition. However, as discussed previously, these lists are somewhat idiopathic to a manufacturer and vary across cultures.

To examine such differences more closely, four examples of attribute (or factor listings – see Appendix 5.3) from two academic researchers and two commercial offerings were compared (Petiot et al. 2009, Tonetto and Desmet 2016).

The first academic list, *'A cross-cultural study of users' craftsmanship perceptions in vehicle interior design'* (Petiot et al. 2009) shows 22 attributes from a paper looking at a subject close to the heart of PQ – craftsmanship. Yet another with just 15 from a study considers an ergonomic viewpoint – *'Why we love or hate our cars: A qualitative approach to the development of a quantitative user experience survey'* (Tonetto and Desmet 2016). The Appendix also shows two attribute charts from the commercial world. There is clearly no agreement on how many attributes is correct, nor what they should be. The commercial lists do show more of a focus on costs of ownership rather than strict PQ factors shown by academics.

5.2.4 The Customer's view of attributes

The Customer view has been more widely researched, but perhaps the most compelling is that by Kukova (2016). This research formulated and collected the eleven factors shown (in list ***K***) by careful survey and literature research which asked participants about the attribute and sub-attributes, which had been carefully developed from the research. An interesting new attribute which had not previously been investigated by the commercial surveys was that of cyber-security, reported in the media through a series of targeted vehicle thefts (Andrews, 2017). We will accept this new attribute, but not include it in the analysis. This is an area for future research.
Attempting to capture the Voice of the Customer is fraught with difficulties as many customer 'needs' are unspoken. Customers are well used to assessing product quality by directly interfacing with or using it and "associate with them a PQ to motivate and give reason to their purchasing decisions" (Carulli, Bordegoni and Cugini 2013: 893).

This is shown by the emotive language which is regularly employed by manufacturers in advertising and selling product, especially motor vehicles, already presented in section 2.2.5. Literature has shown that conveyance of emotional language has a significant effect on bias and attitudes to the voice of the customer (Clark, Dorazelski and Draganska 2009).

Kukova (2016) also breaks down the purchasing and vehicle ownership experience into three distinct phases and examined the factors involved. The research argues that there is little agreement on what are the vital product attributes and their comparative significance. There is an attempt to correct this, suggesting that there is a significant change in attribute importance throughout the purchase 'journey' shown in Fig. 5.2following.

The three phases of this journey were broken into three components, showing the customer journey from initial research to vehicle choice and ownership.

Research

Dealer visit

Ownership

Fig. 5.2. Three phases of the hire/purchase journey for a vehicle

In many countries some form of hire purchase or personal contract purchase is currently in vogue, where the vehicle may never be truly owned by the customer, but a similar three-phase process is still valid, with the final stage being part-ownership, full ownership or exchange for a newer vehicle.

Ownership is relevant here as a desire to own a vehicle is driven in a large part by the PQ element. Ownership is relevant to OEMs as they derive their cash-flow from vehicle sales.

Accounting for the many different ways of becoming an owner- or user-driver, there is little agreement on what the definitive factors are describing ownership or usage. Even the top three factors differ widely between surveys within the same time period and even within the same markets.

Another difficulty is the narrative and descriptors used to define the factors presented to customers against which they are expected to provide a rating. This therefore casts doubt upon the very validity of any results collected by these commercial concerns, who make a living selling the 'data' harvested. For example, below in Fig. 5.3 is shown the 2018 winner of the Driver Power survey by on-line/print magazine Auto Express. Just what does ride and handling mean to a customer? An automotive expert may well know about terms like primary and secondary ride, damping, turn-in, articulation etc., but a novice would not have the same definition or mental model.

Fig. 5.3. Auto Express Driver Power award winner (Auto Express 2018).

5.2.5 Attributes from a woman's viewpoint – the WWCOTY (Women's World Car of The Year)

New emerging research is shown from the discovery of a co-ordinated female viewpoint. We have so far considered attributes from the worlds of commerce, manufacturing and academia, but presented here is a recent move to voice a solely female perspective. The background to this viewpoint is in Appendix 5.4.

The original WCOTY awards are made through judges in many countries, but there has traditionally been a mostly male make-up of the judging panel. Such awards are used by manufacturers to add credence to their advertising, as shown below in Fig. 5.4.

Fig. 5.4 WCOTY (World Car of the year) 2018 – Volvo XC and What Car COTY Kia Stinger (Kia UK 2018).

5.2.6 A Commercial viewpoint

A commercial viewpoint is different to the preceding Audit assessment, described in Chapter 2.2.1, in many ways. This process is created by a number of different commercial undertakings and then sold to manufacturers (with full data analysis and other support services) or made available in summary form to members of the general public through magazines and web-sites. There are many companies across the world providing these sorts of services and have very few common attributes or factors. Some factors are listed below, from the J D Power IQS (Initial Quality Survey), the factors are taken from an assessment of ownership experience at 90 days and also one year on from purchase.

1. Overall Quality
2. Overall Quality Mechanical
3. Powertrain Quality (engine, transmission and driveline)
4. Body and Interior Quality and Design
5. Features and Accessories Quality and Design
6. Overall Design Quality

Appendix 5.3 shows listings of other different views of attributes to show that there is currently little or no agreement on quality, quantity or wording. The Method section following will take examples of attributes from three sources and compare and contrast, leading to an experiment with PQ professionals in an OEM.

Having examined the research on attributes and seen the wide variety of these used by commerce, manufacturing and examined in academia, we will now consider the research question looking for a single list of attributes; is one list possible? The following survey methodology will attempt to answer this question.

5.2.7 Attribute viewpoints analysed via ISM

The conclusion from these views of PQ attributes is that they are continually evolving and that there is little or no agreement on their number or definition.

The use of ISM (Warfield 1974 in Hughes *et al*. 2016) to give some better shape to define PQ attributes, is thought to be the first such application of this technique on automotive PQ.

ISM considers factors and attempts to assess relationships between them by systematic (computer-based) analysis. The previous introduction of three areas (academia, commerce and industry) where factors or attributes pertaining to PQ are discussed has revealed that there is little agreement between them as to which are the real factors that customers and prospects have in mind. Ideally Factor Analysis would have been a good tool to use here, but insufficient data meant this was not possible, so ISM was employed instead.

5.3 Method

Reasons for selecting this method for the study on the OEMs

- ISM was considered appropriate here to examine relationships between seemingly unrelated factors.
- ISM was new to this researcher and therefore a learning opportunity presented itself.
- To the researcher's knowledge, ISM had never been used in a PQ study to date.
- ISM uses pair-wise comparisons, which seems appropriate for analysis of the research questions.

Other methods could have been employed, such as structured interviews. Two of these were successfully trialled during the research; one was the interview at Triumph Motorcycles in Appendix A2.6, and the other was when the original thesis intended to look at PQ in other industries in Appendix A5.5.

Structured interviews were employed for Chapter 6 and were used in the pilot survey using an Excel version of the enhanced Product Impact Model in section 6.3.1.1.

Such interviews would not enable analysis between enablers or factors. ISM does this and provides a structure of the relationships.

5.3.1 ISM applied to PQ

The method employed here was ISM, which was introduced in Chapter 1.7.2.

There are many ways to examine data of this nature, whereby factors are considered relative to one another and their weighting or relative importance is considered. One such technique is ISM. The innovative application of ISM in better understanding PQ is presented here, while also suggesting a definitive measure of PQ that fills a gap in current knowledge. Before we look at ISM in more detail, we will consider three attribute lists, which were derived as a result of the literature survey into attributes discussed earlier in Chapters 2.2 and 3.3.

5.3.2 Survey design - why three sets of attributes?

In order to gather information about PQ, three lists were studied of attributes, one from academia, a second from commerce and a third from industry. These are perhaps the three main perspectives or considerations in this area, and this resulted in one study with two components –

a) Discussion of attribute lists and

b) Analysis via ISM

a) Discussion of attribute lists

The first of two components of the main study was to investigate opinions of OEM 'Experts' - whose day-to-day job is the management and definition of PQ in their Company – these opinions were then sought on these lists. Thus, a workshop was conducted that would involve these SMEs (Subject Matter Experts) who were presented with the same lists of PQ attributes. This meant face-to-face interviews with participants and it was hoped to glean more about real PQ management and deployment in an OEM in 2017. This was felt to be preferable to a remote survey, as more engagement could be made in debate and discussion.

b) Analysis via ISM

This second component of the study followed the selection of one agreed list and was a method of looking at relationships between the attributes within the chosen list. None of the participants had used such a tool before, so some explanation was necessary.

As an approach, ISM has been used to assess issues within sustainable manufacture, (Thirupathi, Vinodh 2016)the supply chain,(Soni, Jain et al. 2014) and in Information Systems (Hughes et al. 2016).

5.3.3 Participants

The participants were the PQ management team of a major OEM that produces two distinct brands of premium product. A total of five all-male participants, management representatives from the PQ Department, took part in this workshop. The mean age was 40 (SD 3.5) years and the total of PQ experience of the SMEs added up to around 45 years. These are the nominated custodians of PQ within the OEM and unprecedented access was given to them. It has to be noted that it had taken nearly a year of negotiation to gain such access and was only secured because a previous colleague had joined this group and therefore became an 'ally within'.

5.3.4 Materials

Over the last forty years, there have been many different factors or attributes defined as being important in considering PQ. There are however several different attributes that show insight into how manufacturers define PQ. In this study, we will consider three different sets of attributes.

- The first set was a result of an academic research study which looked at the car buying process as a whole, (shown as the '***K***' list Kukova 2016).
- The second set was taken from the commercial world of selling a PQ data collecting service to automotive customers and manufacturers, (shown as the ***'N'*** list). The exact source of this list is confidential.

- The third was taken from a now defunct manufacturer, which had influences from Honda and BMW, (shown as the '***M***' list)

The three sets of attributes came about from the literature research. The choices of one each from academia, commerce and industry was considered to be a small enough group to be presented to survey the PQ professionals.
An industry list was taken to be familiar and relevant to the PQ team. The roots and make-up of the three lists are discussed later in this thesis, with definitions of where each attribute or group of attributes came from. They are shown following in Table 5.1 in the exact form in which they were presented to the OEM PQ team.

Table 5.1. The three attribute lists presented for the ISM study

Perceived Quality Attributes					
N list		K list		M list	
	Attributes		Attributes		Attributes
N_1	Interior texture and tactility	K_1	Reliability	M_1	Ergonomics, comfort, access
N_2	Gaps and profiles	K_2	Safety	M_2	Operating loads, efforts, ease of use
N_3	Panel finish	K_3	Security	M_3	Build Quality, fit and finish
N_4	Colour	K_4	Cost of ownership	M_4	Aesthetics, appeal, design
N_5	Exterior tactility	K_5	Vehicle dynamics	M_5	NVH, inc. ICE
N_6	Garnish/highlights	K_6	Practicality	M_6	Comprehensibility, clarity
N_7	Odour	K_7	Comfort	M_7	Tactility
N_8	Surfacing and transitions	K_8	HMI	M_8	Room, length, width, height
N_9	Control loads	K_9	Build quality	M_9	Colour
N_{10}	Function / ease of use	K_{10}	Interior/exterior styling	M_{10}	Driveability, performance
N_{11}	Wheels and tyres	K_{11}	Brand image	M_{11}	Durability

5.3.5 Procedure

Prior to showing these three lists to the PQ experts, the same three had already been piloted on industry colleagues with expertise in a Quality background to see if the process of choosing one 'best fit' worked and made sense, which seemed to be the case. The specific pilot and main surveys used here took place across two months in mid-2017.

Three sets were presented to cover three research areas (academia, commerce and industry) as two would have seemed too much of a binary choice and any more than three would have been too taxing in terms of the limited time to which access to these participants had been granted.

Due to time and availability constraints, the workshop had to be held when a maximum number of the SMEs were available.

They were assembled in a room, given a short briefing on the thesis research as background and appraised of the nature of the survey in context with the other two surveys (Chapter 4 on Engineers and Chapter 6 on Customers). Examples of research material was shown to the SMEs.

This researcher facilitated the workshop, held in a quiet conference room with no interruptions. It was important that the participants followed the structured process of listen (to background and instructions), discuss (the three attribute lists), decide (upon the 'best-fit' list) and then agree how each attribute was related or not to the others (see Fig. 5.5 following). We could then begin the ISM process.

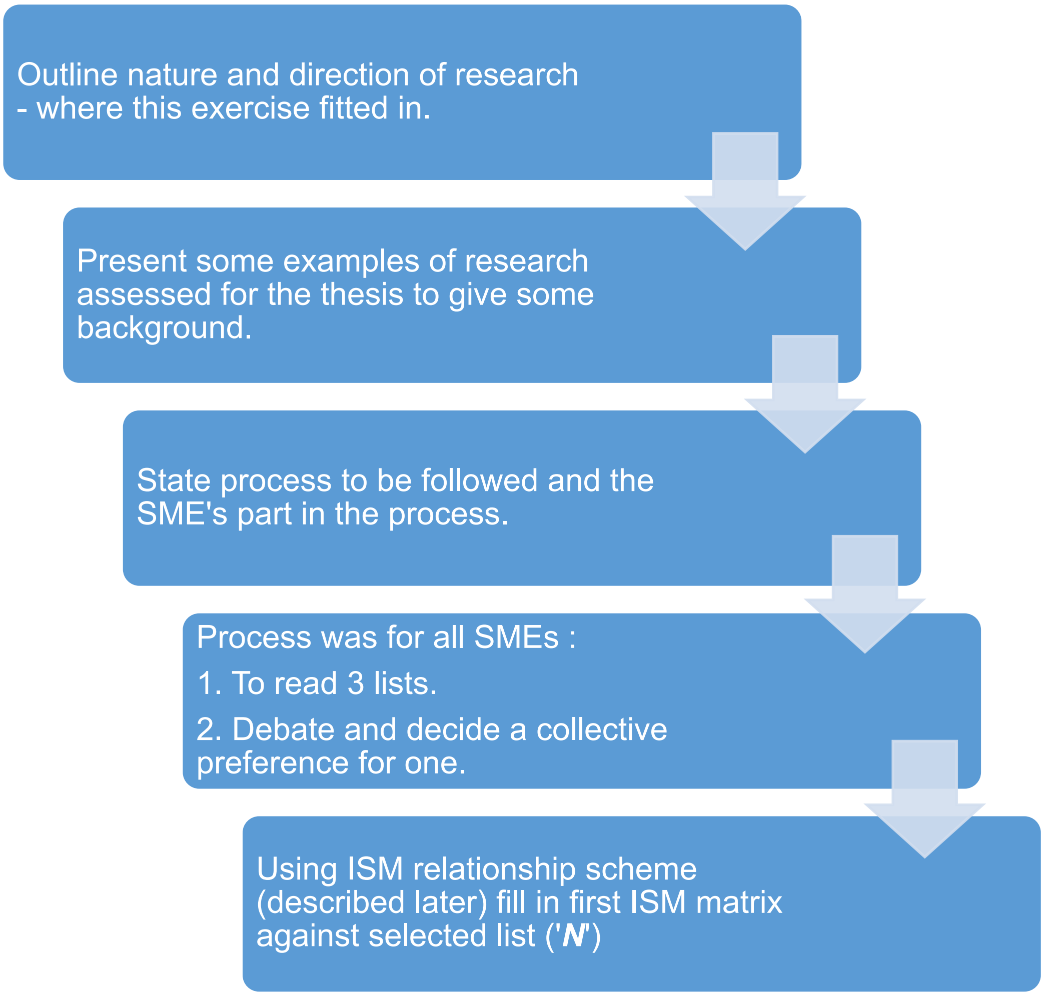


Fig. 5.5. Flow-chart for workshop procedure (Author).

The PQ team were shown the separate lists in Table 5.1 for the first time as a group and asked to select together the one which *most closely* represented their view of the best set of PQ attributes.

It was then only necessary to complete step one of ISM in the workshop to create the first matrix. These attributes were later analysed through the full ISM process, which is set out in the flow-chart following in Fig. 5.6.

The first stage of ISM asks participants to assess how attributes are related and if one supports or enables another against the following legend: -

V, where attribute *i* will accomplish or impact upon *j*.
A, where attribute *j* will be accomplished or be impacted upon by *i*.

X, where attribute *i* and *j*will impact upon each other.
O, where there is no relationship.

This is to create the Structural Self-Interaction Matrix shown in Table 5.2 of the Results section (SSIM).

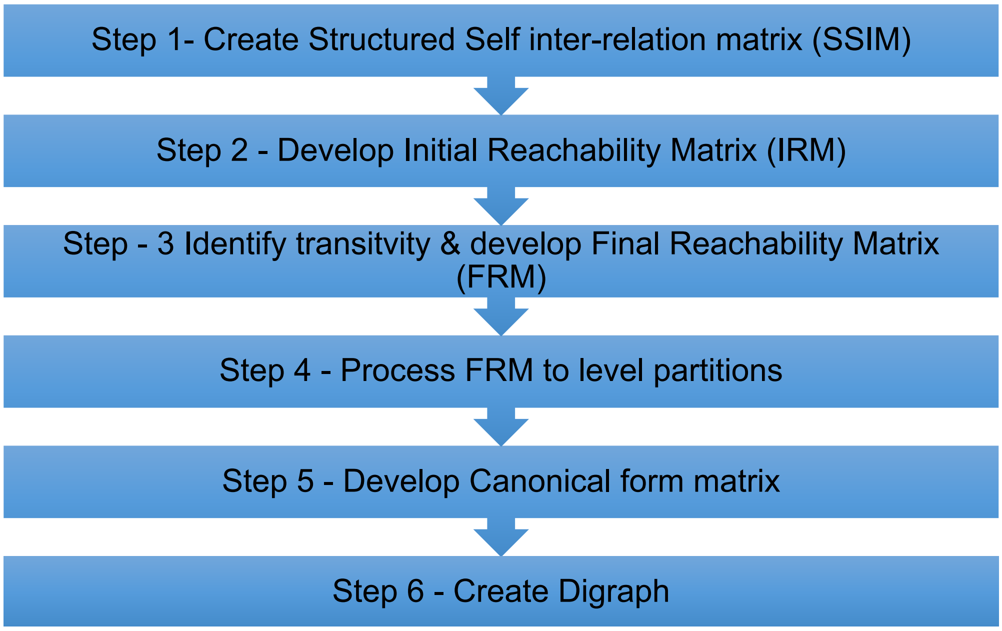


Fig. 5.6. The ISM process flow.

The ISM process flow above, demands that debate is held over the factors to be analysed. Driven by personnel availability, this had to be completed in the one meeting with all managers present.

Once one list of attributes was agreed and selected – this was list '***N'*** – the ISM process could begin. The '***N'*** list was also the most often chosen during the pilot phase described in 5.2.4

The first stage of the ISM analysis takes the attribute list – '***N***' – that most closely met the collective PQ Management team's view and then ranked each attribute against the others. See later, section 3 Results for the process. This was in essence, a pair-wise comparison.The full detail behind each step is shown in the Results section.

5.4 Results

The workshop was a useful exchange of views and achieved what was set out, with the right people present, i.e. the discussion of three attribute lists, then choosing one to best represent the OEM's PQ function views. This was then scored through the ISM process.

The initial feedback from the participants was that none of the three lists of attributes quite fully satisfied any of the reviewing managers. All lists were thought incomplete or slightly flawed, but as no two managers were able to agree on a list anyway, they were asked to pick the one that *most closely* represented their view of PQ. The ISM process was then started, with only Stage 1 conducted with all the team present, as the following stages were created as a result of post-processing Stage 1 manually.

The chosen list of attributes – '***N***' is shown below, super-imposed over a Tesla Model 'S' in Fig. 5.7.

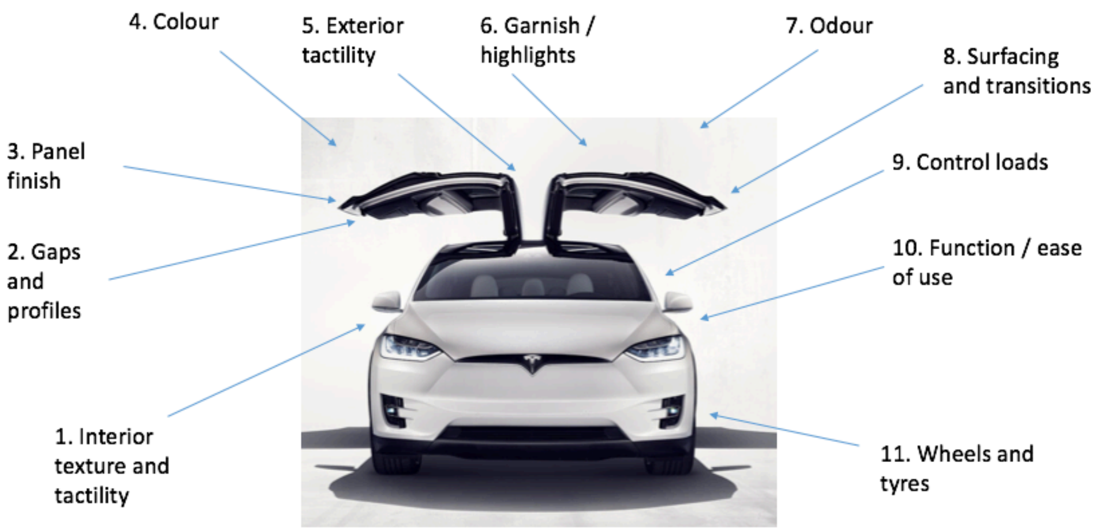


Fig. 5.7. Resultant list of attributes as list '**N**' (Tesla 2019)

The results of the workshop on Step 1 shown following in Table 5.2, to produce the SSIM was all that was required from the workshop itself. This stage was the input matrix for all following stages. Any further assessment of factor relationships was computed manually and checked by the ISM processing software, which using Excel as a base, compares the factors or attributes with each other as pairwise comparisons looking for relationships. The process concludes with a MIMAC (*Matrice d'impact croise-multiplication enclassement*) and is described in full below, starting with Table 5.2. The manual processing at each stage was over-checked through ISM software. Driving and dependent factors - or attributes in this case - will be identified. The former exercise a significant effect on the others, whereas the latter rely heavily upon the other attributes.

<u>Step 1</u>

A workshop was convened of experts who were asked for their opinion on the interaction of 11 factors. The ISM process was only briefly explained to them, as the point of the workshop was only to create the first matrix and conduct pairwise comparisons.

The first stage of ISM is an examination of the basic relationships between several factors (self-interaction T_1 to T_n), to see if any of the following hold and are marked thus:

V, where attribute *i* will accomplish or impact upon *j.*
A, where attribute *j* will be accomplished or be impacted upon by *i*.
X, where attribute *i* and *j*will impact upon each other.
O, where there is no relationship.

This is to create the Structural Self-Interaction Matrix (SSIM).

The 11 attributes proposed and agreed by the meeting were assessed according to the above and the following table 5.2 produced.

Table 5.2. PQ using 11 factors as agreed by OEM PQ Management.

Perceived Quality Enablers - Group N JLR PQ

(*j*)	Enabler (*i*)	N_{11}	N_{10}	N_9	N_8	N_7	N_6	N_5	N_4	N_3	N_2	N_1
N_1	Interior texture and tactility	O	A	V	X	V	X	O	V	X	X	
N_2	Gaps and profiles	O	X	V	X	O	V	X	V	X		
N_3	Panel finish	O	X	O	X	O	A	X	X			
N_4	Colour	V	A	O	A	O	X	V				
N_5	Exterior tactility	A	A	A	X	O	A					
N_6	Garnish/highlights	V	A	A	X	O						
N_7	Odour	O	O	O	O							
N_8	Surfacing and transitions	V	X	X								
N_9	Control loads	O	X									
N_{10}	Function / ease of use	O										
N_{11}	Wheels and tyres											

This shows that in their expert view, attribute N_i is, or is not related to factor $N_j$according to the four relationship definitions. Clearly, attribute N_1 is related to itself and so on to N_{11}, so that is where the matrix finishes at this stage.

Step 2

An Initial Reachability Matrix (IRM) is now developed. In this next part of the ISM process, the cells in the SSIM are transposed thus:

i. In the SSIM co-ordinates for (*i, j*), a V entry becomes 1 and the (*j, i*) cell shows 0 – zero;
ii. In the SSIM A entry for (*i, j*), becomes 0 and opposing (*j, i*) cell shows 1;
iii. In the SSIM X entry for (*i, j*), becomes 1 in the IRM and (*j, i*) cell also shows 1;
iv. In the SSIM O entry for (*i, j*), becomes 0 in the IRM and (*j, i*) cell also shows 0.

This converts the original alpha data to binary format, which is necessary for further analysis. The result of this exercise is called the IRM, or Initial Reachability Matrix. This takes the SSIM and reflects it on itself, to then fill in the other half of the matrix.

The result from Step 2 (the IRM) is shown below in Table 5.3:

Table 5.3. The IRM

	Perceived Quality Enablers - Group N JLR PQ											
(*j*)	**Enabler (*i*)**	N_{11}	N_{10}	N_9	N_8	N_7	N_6	N_5	N_4	N_3	N_2	N_1
N_1	Interior texture and tactility	1	1	1	1	0	1	1	1	1	0	0
N_2	Gaps and profiles	1	1	1	1	1	1	0	1	1	1	0
N_3	Panel finish	1	1	1	1	1	0	0	1	0	1	0
N_4	Colour	0	0	1	1	1	1	0	0	0	0	1
N_5	Exterior tactility	0	1	1	0	1	0	0	1	0	0	0
N_6	Garnish/highlights	1	0	1	1	1	1	0	1	0	0	1
N_7	Odour	0	0	0	0	0	0	1	0	0	0	0
N_8	Surfacing and transitions	1	1	1	1	1	1	0	1	1	1	1
N_9	Control loads	0	0	0	0	1	1	0	1	1	1	0
N_{10}	Function / ease of use	1	1	1	1	1	1	0	1	1	1	0
N_{11}	Wheels and tyres	0	0	0	0	1	0	0	0	0	0	1

Step 3

The next stage is to look for other relationships, as it is logical to suggest that if factor a is related to b and b to c, then a and c may also be related. This is called Transitivity.

When a connection is shown to exist between the first and second of a list of factors and between the second and third, then a connection between first and third demonstrates a transitive link. Note that the order of the columns also changes from reverse numerical to straight numerical.

Transitivity examination is conducted in two stages; through the IRM and then again through the FRM or Final Reachability Matrix.

Professor Warfield, the original promoter of ISM, stated that "By continuing to compare Alternatives in pairs, using the process just described, a relationship of preference is built up on the Alternatives. This means that one can draw a tentative preference structure for the set of Alternatives based on the paired comparisons of Alternatives" (2002: 99).

This is a key stage of the process, which is taken as a series of actions:

1. Look across the first row of the matrix and note the column heading where a 1 appears. Do this for all rows, noting each instance of 1, ignoring n:n situations.

2. Whenever a 0 is encountered across the full row (*j*), see if a 1 from the previous action is reflected, but now in the column.
3. If there is a match, then the 0 becomes 1*.
4. Repeat this search for matches and replace the 0 with 1*.
5. Continue until the whole matrix is checked for transitivity.

For example,

1. Factor N_2 in the first row (when assessed against factor N_1) shows a 0.
2. The column for N_1 assessed against N_2 shows a 1.
3. This is a match and so a 1* is reflected.

The result of this process is shown in the FRM below in Table 5.4:

Table 5.4. The FRM.

(*j*)	**Enabler (*i*)**	N_1	N_2	N_3	N_4	N_5	N_6	N_7	N_8	N_9	N_{10}	N_{11}
N_1	Interior texture and tactility	1	1	1	1	1*	1	1	1	1	1*	1*
N_2	Gaps and profiles	1	1	1	1	1	1	1*	1	1	1	1*
N_3	Panel finish	1	1	1	1	1	1*	1*	1	1*	1	1*
N_4	Colour	1*	1*	1	1	1	1	0	1*	0	1*	1
N_5	Exterior tactility	1*	1	1	1*	1	1*	0	1	1*	1*	1*
N_6	Garnish/highlights	1	1*	1	1	1	1	1*	1	1*	1*	1
N_7	Odour	0	0	0	0	0	0	1	0	0	0	0
N_8	Surfacing and transitions	1	1	1	1	1	1	1*	1	1	1	1
N_9	Control loads	1*	1*	1*	1*	1	1	0	1	1	1	1*
N_{10}	Function / ease of use	1	1	1	1	1	1	1*	1	1	1	1*
N_{11}	Wheels and tyres	0	1*	1*	0	1	0	0	1*	0	0	1

<u>Step 4</u>

The FRM must now be partitioned, which means that over several levels, relationships between factors are again examined to see if they support each other.

Levels of matching factors are examined, to see if they support each other for Reachability and antecedents. Reachability is the combination of the factor itself, plus all other factors it helps to achieve. The antecedents are the factor itself and other factors which may support it. The co-incidence of reachability and antecedents is shown as the intersection column.

This is achieved by listing the factors in a column, then taking the rows in the FRM and listing the factors in that row [the Reachability set, or (R(Pi]) then listing those numbers in the corresponding column [the Antecedent set A(Pi)]. The intersection of these two lists is then listed. This first set is denoted as Level I, where the Intersection equals the Reachability set. See following in Table 5.5.

Table 5.5. Level I iteration

(*j*)	Enabler (*i*)	Reachability Set R(Pi)	Antecedent Set: A(Pi)	Intersection R(Pi) & A(Pi)	Level
N_1	Interior texture ar	1,2,3,4,5,6,7,8,9,10,11	1,2,3,4,5,6,8,9,10	1,2,3,4,5,6,8,9,10	
N_2	Gaps and profiles	1,2,3,4,5,6,7,8,9,10,11	1,2,3,4,5,6,8,9,10,11	1,2,3,4,5,6,8,9,10,11	
N_3	Panel finish	1,2,3,4,5,6,7,8,9,10,11	1,2,3,4,5,6,8,9,10,11	1,2,3,4,5,6,8,9,10,11	
N_4	Colour	1,2,3,4,5,6,8,10,11	1,2,3,4,5,6,8,9,10	1,2,3,4,5,6,8,10	
N_5	Exterior tactility	1,2,3,4,5,6,8,9,10,11	1,2,3,4,5,6,8,9,10,11	1,2,3,4,5,6,8,9,10,11	I
N_6	Garnish/highlight	1,2,3,4,5,6,7,8,9,10,11	1,2,3,4,5,6,8,9,10	1,2,3,4,5,6,8,9,10	
N_7	Odour	7	1,2,3,6,7,8,10	7	I
N_8	Surfacing and tra	1,2,3,4,5,6,7,8,9,10,11	1,2,3,4,5,6,8,9,10,11	1,2,3,4,5,6,8,9,10,11	
N_9	Control loads	1,2,3,4,5,6,8,9,10,11	1,2,3,5,6,8,9,10	1,2,3,5,6,8,9,10	
N_{10}	Function / ease o	1,2,3,4,5,6,7,8,9,10,11	1,2,3,4,5,6,8,9,10	1,2,3,4,5,6,8,9,10	
N_{11}	Wheels and tyres	2,3,5,8,11	1,2,3,4,5,6,8,9,10,11	2,3,5,8,11	I

Table 5.6. Level II iteration.

(*j*)	Enabler (*i*)	Reachability Set R(Pi)	Antecedent Set: A(Pi)	Intersection R(Pi) & A(Pi)	Level
N_1	Interior texture ar	1,2,3,4,6,8,9,10	1,2,3,4,6,8,9,10	1,2,3,4,6,8,9,10	II
N_2	Gaps and profiles	1,2,3,4,6,8,9,10	1,2,3,4,6,8,9,10	1,2,3,4,6,8,9,10	II
N_3	Panel finish	1,2,3,4,6,8,9,10	1,2,3,4,6,8,9,10	1,2,3,4,6,8,9,10	II
N_4	Colour	1,2,3,4,6,8,10	1,2,3,4,6,8,9,10	1,2,3,4,6,8,10	II
N_6	Garnish/highlight	1,2,3,4,6,8,9,10	1,2,3,4,6,8,9,10	1,2,3,4,6,8,9,10	II
N_8	Surfacing and tra	1,2,3,4,6,8,9,10	1,2,3,4,6,8,9,10	1,2,3,4,6,8,9,10	II
N_9	Control loads	1,2,3,4,6,8,9,10	1,2,3,6,8,9,10	1,2,3,6,8,9,10	
N_{10}	Function / ease o	1,2,3,4,6,8,9,10	1,2,3,4,6,8,9,10	1,2,3,4,6,8,9,10	II

This process is repeated, with successive Levels excluding those that have been identified earlier, i.e. factors 5, 7 and 11 being removed from the next iteration, as above in Table 6.

The final iteration leaves just factor 9:

Table 5.7. Level III final iteration

(*j*)	Enabler	Reachability Set R(Pi)	Antecedent Set: A(Pi)	Intersection R(Pi) & A(Pi)	Level
N_9	Control loads	9	9	9	III

Step 5

The FRM once partitioned, is re-developed into the CFM (Canonical Form Matrix), to form clusters aligned to the partitioning. The factors have been re-ordered in this stage and those to the left would normally in ISM show up as the top level in the ISM model. To show the working, the factors are listed to the right, with their levels assigned.

The digit 1 is inserted in the cell to show the presence of the factor in the list. A zero is inserted if there is no factor listed. This result is shown following in Table 5.8.

Table 5.8. Canonical form.

Enabler	N_5	N_7	N_{11}	N_1	N_2	N_3	N_4	N_6	N_8	N_{10}	N_9	Level	Reachability Set: R(Pi)
Exterior tactility	1	0	1	1	1	1	1	1	1	1	1	1	1,2,3,4,5,6,8,9,10,11
Odour	0	1	0	0	0	0	0	0	0	0	0	1	7
Wheels and tyres	1	0	1	0	1	1	0	0	1	0	0	1	2,3,5,8,11
Interior texture and tactility	1	1	1	1	1	1	1	1	1	1	1	2	1,2,3,4,5,6,7,8,9,10,11
Gaps and profiles	1	1	1	1	1	1	1	1	1	1	1	2	1,2,3,4,5,6,7,8,9,10,11
Panel finish	1	1	1	1	1	1	1	1	1	1	1	2	1,2,3,4,5,6,7,8,9,10,11
Colour	1	0	1	1	1	1	1	1	1	1	0	2	1,2,3,4,5,6,8,10,11
Garnish/highlights	1	1	1	1	1	1	1	1	1	1	1	2	1,2,3,4,5,6,7,8,9,10,11
Surfacing and transitions	1	1	1	1	1	1	1	1	1	1	1	2	1,2,3,4,5,6,7,8,9,10,11
Function / ease of use	1	1	1	1	1	1	1	1	1	1	1	2	1,2,3,4,5,6,7,8,9,10,11
Control loads	1	0	1	1	1	1	1	1	1	1	1	3	1,2,3,4,5,6,8,9,10,11

Step 6

A Driving and Dependence power is applied to the CFM to assess what factors really drive the process.

This is achieved by summing the columns and rows as below in Table 5.9:

Table 5.9. Driving factors

(*i*)	Enabler	N_5	N_7	N_{11}	N_1	N_2	N_3	N_4	N_6	N_8	N_{10}	N_9	Driving Power	Reachability Set: R(Pi)
N_5	Exterior tactility	1	0	1	1	1	1	1	1	1	1	1	10	1,2,3,4,5,6,8,9,10,11
N_7	Odour	0	1	0	0	0	0	0	0	0	0	0	1	7
N_{11}	Wheels and tyres	1	0	1	0	1	1	0	0	1	0	0	5	2,3,5,8,11
N_1	Interior texture and tactility	1	1	1	1	1	1	1	1	1	1	1	11	1,2,3,4,5,6,7,8,9,10,11
N_2	Gaps and profiles	1	1	1	1	1	1	1	1	1	1	1	11	1,2,3,4,5,6,7,8,9,10,11
N_3	Panel finish	1	1	1	1	1	1	1	1	1	1	1	11	1,2,3,4,5,6,7,8,9,10,11
N_4	Colour	1	0	1	1	1	1	1	1	1	1	0	9	1,2,3,4,5,6,8,10,11
N_6	Garnish/highlights	1	1	1	1	1	1	1	1	1	1	1	11	1,2,3,4,5,6,7,8,9,10,11
N_8	Surfacing and transitions	1	1	1	1	1	1	1	1	1	1	1	11	1,2,3,4,5,6,7,8,9,10,11
N_{10}	Function / ease of use	1	1	1	1	1	1	1	1	1	1	1	11	1,2,3,4,5,6,7,8,9,10,11
N_9	Control loads	1	0	1	1	1	1	1	1	1	1	1	10	1,2,3,4,5,6,8,9,10,11
Dependence Power		10	7	10	9	10	10	9	9	10	9	8		

Fig. 5.8 following shows how a blank MIMAC looks and what each quadrant shows in terms of a relationship or otherwise between two attributes in this case, ***i*** and ***j***. Driving Power means that one attribute drives another and Dependence Power is the inverse.

The actual end result is shown in Fig. 5.9. This shows on a graph the relative positions of each attribute and in this case that most attributes are closely related. 1, 6 and 10 (Interior texture and tactility, Garnish/highlights and Function/ease of use) are grouped together.

If one imagines for example, a door release handle, this is usually chromed metal or plastic and functions to open the door. The latter are at a similar Driving Power of 11 to 2, 3 and 8 (Gaps and profiles, Panel finish and Surfacing and transitions).

An example here could be a fuel filler flap, which has to have a gap to the body side to be able to open, feel smooth to the touch and needs to be level with the surrounding panel to look and feel part of the assembly.

Attribute 9, (Control loads, or the measurable effort required to operate the control, switch, lever or handle) sits at a lower Driving Power along with 5 (Exterior tactility), but 9 is a lower Dependence Power than 5. Attribute 4 (Colour), sits alone at a Driving Power of 9, so still high, but at the same Dependence Power of 9 as the grouping of 1, 6 and 10 (Interior texture and tactility, Garnish/highlights and Function/ease of use).

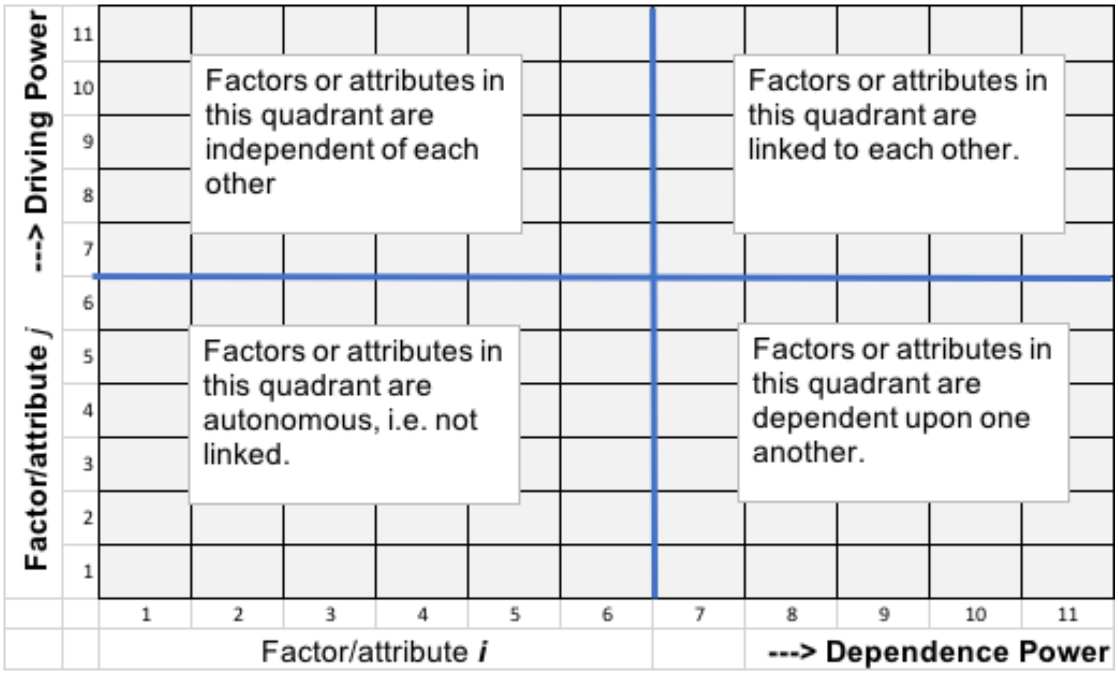


Fig. 5.8.A blank ISM MIMAC, showing sectors

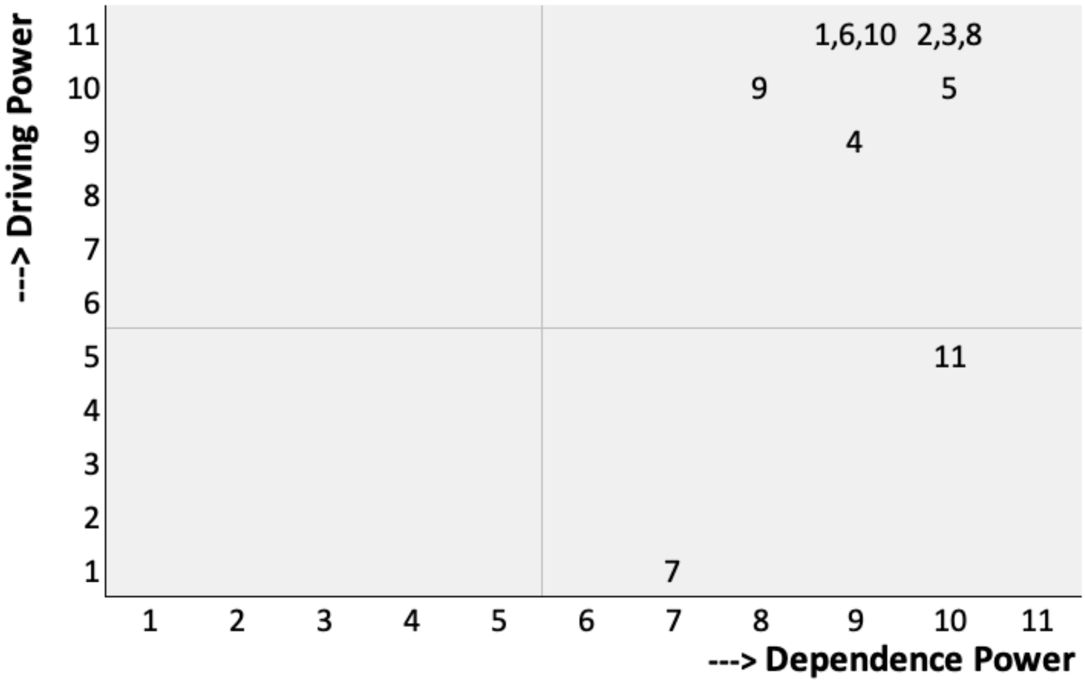


Fig. 5.9. Driving Power/Dependence Power MIMAC for OEM survey.

On their own and not closely related to the other attributes sit 7 (Odour) and 11, (Wheels and Tyres). Wheels and Tyres sits just below the split of the top left-hand quadrant where factors are linked at a Driving Power of 6 and dependence of 10. Odour (7) sits at the lowest Driving Power of 1 and lowest Dependence Power of 7 and firmly in the lower left-hand quadrant of attributes dependent upon one another, so alone in this area. Another way of looking at the ISM results is to draw them as a digraph, or distance graph, as in Fig.5.10 following.

Fig. 5.10 following shows the relationships between factors or attributes. Attribute 7 (Odour) is shown on its own, as it is at the lower Driving Power and is logically alone. Attribute 11 (Wheels and Tyres) is also distant from the others, yet still related. Most other attributes are quite close to one another. This is the simple form of the digraph, which shows using distance from each other how the attributes are or are not related, such links are shown with arrows.
This digraph will be examined at the end of the chapter in Fig. 5.16. This is not dissimilar from that found by Stylidis, Wickman and Söderberg (2018).

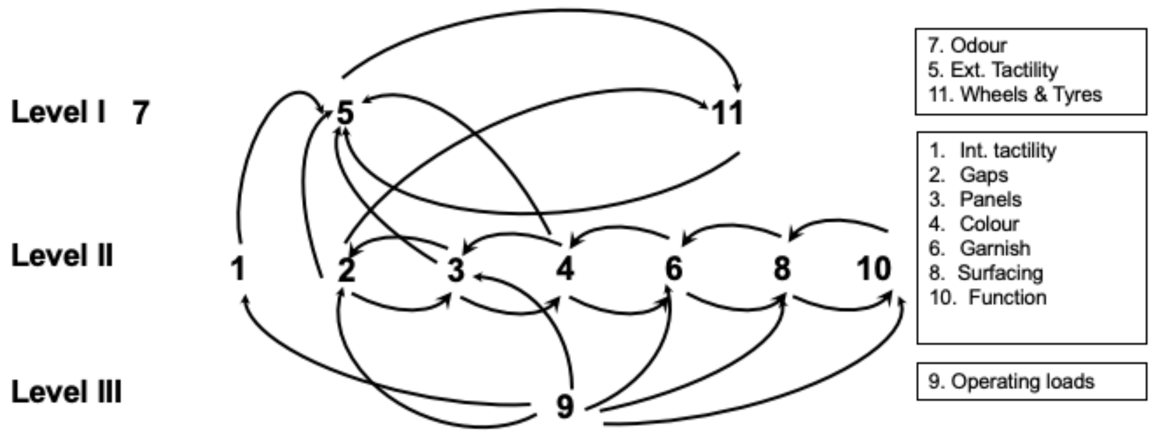


Fig. 5.10. The ISM digraph and the attributes.

The relationships shown by the arrows and the Levels were derived through the ISM process, detailed previously.
We will return to this digraph in section 5.4.3, in the discussion of mental models.

5.5 Discussion

This study was a natural progression from the survey developed and tested in Chapter 4, examining the nature of how Engineers perceive PQ. Here, the way in which manufacturers use, manage and develop PQ attributes was discussed with the managers and therefore was studied by the facilitator. The characteristics and properties associated with attributes were introduced in Chapter 2.2.1, and indicates how important they are to manufacturers, with BMW being given as an example. Little agreement exists in the literature in terms of what particular attributes are important to describe a vehicle. These lists of attributes have been derived from academic research, commercial interests and a manufacturer. Even the number of attributes is not agreed upon, with some lists running to over 20 and one list of just 7 (see chapter Appendix, Tables A5.3 to 5.5, 5.7 & 5.9).

In order to asses these attributes, and to gain an OEM/professional view of PQ, its deployment, measurement, management and relevance to a current manufacturer, a workshop was arranged with the managers responsible for PQ in an OEM. Three lists of attributes were presented to them in order to see if they could agree between themselves that one of the three most closely represented their collective view of PQ in their Company. It was evident from the manner in which the attendees debated and conversed, that despite having a collective experience of PQ measured in decades, that their views were quite institutionalised (all were male, average age of 45, for example, despite there being females in the department).

One of the three lists was duly selected as requested by the facilitator, as being the closest to the group's view of PQ in that OEM, though not a perfect fit, it was preferred over the other two. There was much debate over the inclusion of the last attribute - Wheels and tyres – but all had to agree that in the case of their own Company, these assemblies had played a huge part in creating the iconic designs for which they were responsible in the PQ world.

Following this debate, the closest list to the team's view of PQ attribute definition was put through the ISM process.

The group had nominated list '***N***' from the selection, then the workshop was continued to rate the relationship of each attribute against the others. This used the V, A, X and O legend in the Results section to highlight any relationships between each attribute. Again, the facilitator managed this second half of the workshop and encouraged the participants to concentrate on the job in hand and ensure all points were heard. The decision for the agreed legend label (V, A, X and O) to be applied was unanimous once all understood the process.

The results from the MIMAC are useful in showing that expected closely related attributes came out this way from the ISM process, with the main groupings of 1, 6 and 10 (Interior texture and tactility, Garnish/highlights and Function/ease of use) are grouped together, at a similar Driving Power of 11 to 2, 3 and 8 (Gaps and profiles, Panel finish and Surfacing and transitions). The groupings are in line with a very commercially-driven view of PQ presented in IT specialist Dassault's view (Reese 2015) and more academic views on tactility (Haverkamp 2017, van Laack 2014). Odour being on its own was expected, however its importance is not to be underestimated (see later section 5.4.2).

From the ISM study, for the PQ case, the conclusion was that the factors selected were:

- Vital to PQ
- Linked to one another (excepting Odour and Wheels and Tyres)
- Closely related, i.e. not independent or autonomous
- Supportive of i.e. related to, each other

It should be emphasised that the process of asking PQ Managers (and other industry professionals during the pilot phase) to pick a representative list, showed that it may be possible to capture the essence of PQ in just 11 attributes.

Just in the facts that no female viewpoint was represented and frequent comments along the lines of "we've always done it this way" demonstrated something of an institutionalised approach to PQ.

The data derived from these two mini-studies of a) selecting an agreed attribute list and b) performing an associative or relationship study on the result has shed some light how an OEM regards the subject of PQ.

The data presented in this study and the interaction with the PQ managers at an OEM shows that there is still institutionalised thinking in that particular OEM and that there is room for the type of research presented here to look wider at the subject.

It does point at two issues that stand aside from the main bulk of the attributes examined and give Wheels and Tyres and Odour stand-alone importance. This was recognised by the OEM.

It was also clear that the researcher conducting the exercise and facilitating the workshop was seen very much as an 'outsider' and 'not to be trusted'. The feeling was of being granted access into a hallowed environment for but a short time, to glean snippets of information from an expert team who felt that they were on top of their game.

What was interesting was that in the short preamble to the workshop, some of the research literature examples shown by the facilitator were not familiar to those present. This was despite their obvious direct relevance in one case to an exercise conducted by the PQ team (and supervised by a manager present at the workshop).

Nonetheless, the workshop ran as planned, the three lists were discussed at length with the facilitator encouraging debate such that all points were heard equally and that the expert with the least time served in the department was not overruled by the one with the most. This is a danger with many such institutions where the maxim of "we've always done it that way" often holds up progress and learning.

Due to matters of confidentiality, it is not possible to delve much deeper into OEM PQ issues, other than see the top level such as the insight gained at Triumph Motorcycles (Appendix A2.6), and at Volvo Trucks for example, where Stylidis *et al.* (2015: 172) identified 'Uptime, Innovation, Fuel Efficiency, After Sales Care and the Driver Environment'.

A similar exercise at the Volvo car OEM (quite separate from the trucks company) showed less attributes – ‘Scandinavian design, Strength in every sense and Contemporary Luxury Experience’ (Stylidis *et al.* 2015: 4).

5.5.1 Wheels and tyres, a special attribute

What is interesting is that attribute 11, Wheels and Tyres, stands on its own in the digraph and attracted quite some debate as remarked earlier. Wheels can make a substantial difference to a vehicle’s appearance and the aim of any manufacturer is to use the wheel arch envelope to emphasise that vehicle’s potential.

In this OEM, the attribute had not been driven by any PQ-centred action, but by necessity of product design, i.e. the need for high ground clearance on the 4x4 vehicles (large diameter wheels and deep profile tyres within an overly-large wheel envelope, or size of the wheel-arch area) and large diameter wheels with low-profile tyres) on the sports cars. This is really interesting, considering the emphasis given in this particular OEM to these two subjects. An image of the information on a tyre is shown in Fig.5.11.

Some examples of the emphasis made by OEMs on wheels and tyres follows. Tyres are a complex engineering product and some basic details follow.

The wheel and tyre assembly shown is a 16-inch wheel diameter, shod with a tyre of 205 mm width, showing an aspect ratio of 55%, which is the relationship of tyre depth to width. 91W is the load rating, appertaining to the vehicle weight on the axle.

These assemblies are a mix of metric and imperial units, but such is the international standard.

Fig. 5.11. Wheel and tyre sizes (Black Circles 2018)

A performance car, such as a BMW saloon will be designed such that the wheel fills the envelope, to look purposeful and even aggressive, see the images from their web-site in Fig. 5.12. This site shows nearly 300 options for wheels, tyres and wheel accessories such as trims and snow-chains (BMW UK 2019).

Fig. 5.12. BMW Summer (left) and winter (right) wheel and tyre options (BMW UK 2019)

Not only do performance cars have emphasis placed on the wheel arch envelope – it is also a feature of the burgeoning market for SUV's (Sports Utility Vehicles), such as those popularised by the Nissan Qashqai (which debuted in 2006) and most recently the Skoda Karoq, MG ZS, Hyundai Kona, Volvo XC40, etc.

These types of vehicles enhance their 'ruggedness' appeal by having the opposite relationship of wheel and tyre envelope of a saloon, whereas here a gap above and around the tyre aims to lend an off-road capability to the design. Although many of these SUVs have little or no off-road ability, nor even four-wheel-drive, the manufacturers take this characteristic of a 4x4 and use it to lend credence to their product offering.

An observation may be noted in that according to its own PQ intranet site, a significant attribute of the particular OEM was not mentioned in any of the three lists. Interior lighting ambience was not debated in the workshop and is rarely promoted in this OEM's or many other competitor's marketing information. This attribute is *internally* promoted within the OEM, yet for which it is not especially known, but is very pleasing when experienced. This issue was not raised during the exercise, as the point of the workshop was to see if it were possible to arrive at one agreed list and there was no time or place for facilitator bias to be introduced.

5.5.2 Odour, a singular attribute

Odour has also been singled out by the ISM analysis as an attribute on its own and is discussed further in the Appendix to Chapter 2 (A2.1) on the human senses. Different cultures value odour - or the lack of it – differently (Chen 2017). It showed a very low Driving Power but was nonetheless recognised by the OEM studied as a key attribute. A chance conversation with the UK importer of Chinese luxury coaches revealed an interesting observation. Upon delivery of the first coaches to the UK, as the door was proudly opened to allow inspection, the UK representative had the following reaction:

> "We were proudly shown a tri-axle vehicle in their so-called showroom unit with sumptuous looking ruched leather seats trimmed in surprisingly agreeable shades of chocolate brown and off-white cream… a similar vista to a Walls Viennetta I remember thinking (see Fig. 5.13 below).
>
> But rather than the smell of fresh cut carpet and leather, was the aroma you'd find inside the guts of an old transistor radio.
>
> I questioned this to the sales director who simply told me at this price who cares what the interior smells like.
>
> His answer didn't convince me." (Humble 2019).

Perception is a very powerful issue.

Fig. 5.13. Interior of KL coach, showing "Viennetta" seats (Humble 2019).

5.5.3 Mental model of OEM survey results

In order to bring these perception issues together, as used in Chapter 4, the results of this survey will be shown on a summary as in Fig. 5.14 following. This will lead to a mental model. In this case, we will combine the summary and the ISM digraph results.

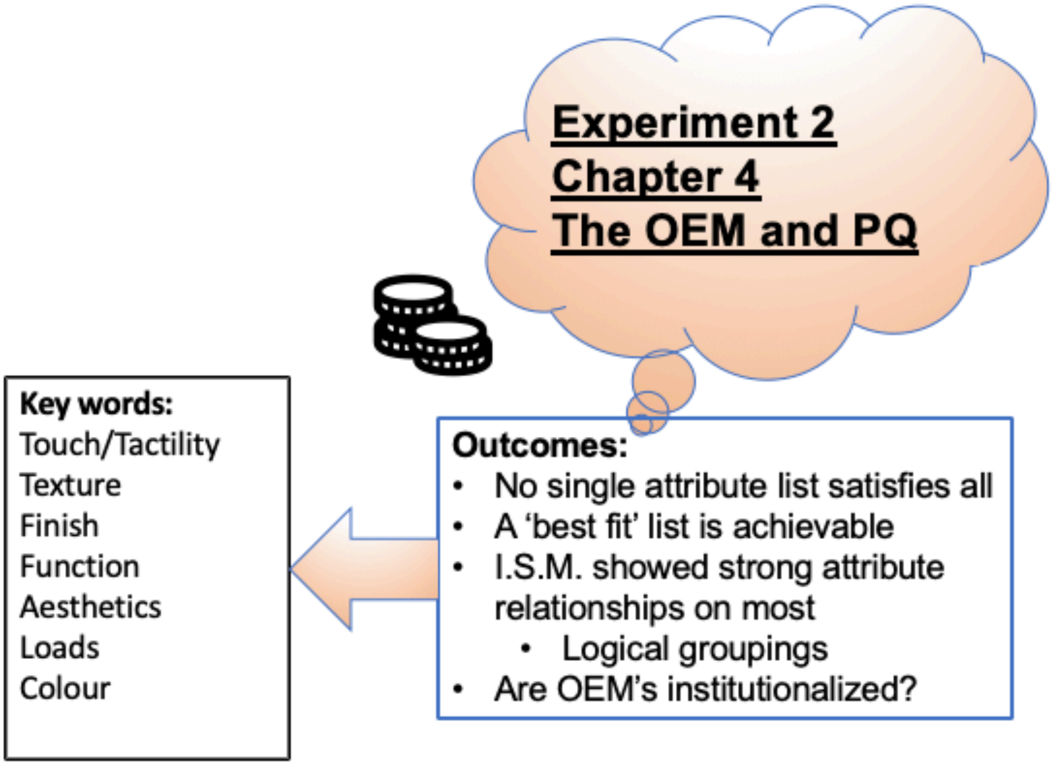


Fig. 5.14. Summary of key words and outcomes for the survey results

The summary in Fig. 5.14 shows the findings from this survey of the OEM and its attitude to PQ, that as expected and declaimed by the PQ team that there is no single list of attributes that satisfies all people. The '***N***' list used for the ISM analysis had proved close enough for them to accept and to start the workshop, as a best fit, where relationships were shown and made logical sense. The key words arising from this Chapter showed a strong visual and tactile aspect.

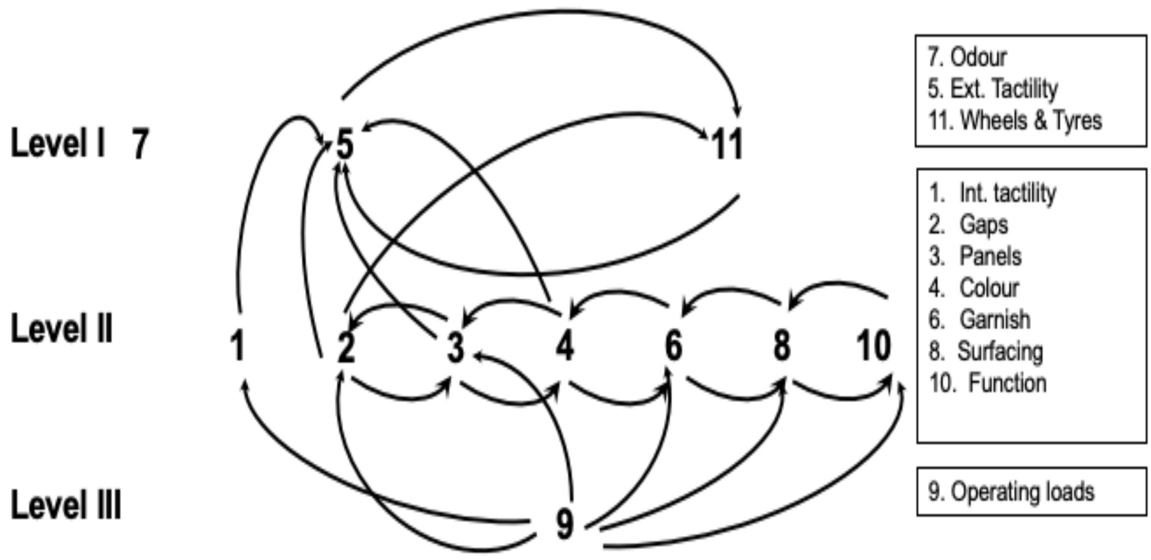


Fig. 5.15. The ISM digraph and the attributes.

Fig. 5.15 shows the combination of the ISM digraph and the three levels (I, II and III) which came out of the ISM process, with the attributes assessed through ISM. The digraph shows the links between and across the levels. Odour remains way out on its own (attribute 7).

Trying to make more sense of the results, if one looks at the combined ISM results and the digraph from Fig. 5.10 enhanced as in Fig. 5.15, and then overlays the effect of time moving forwards as a person becomes acquainted with a vehicle, then a mental model such as that shown in Fig. 5.16is presented as a chapter summary.

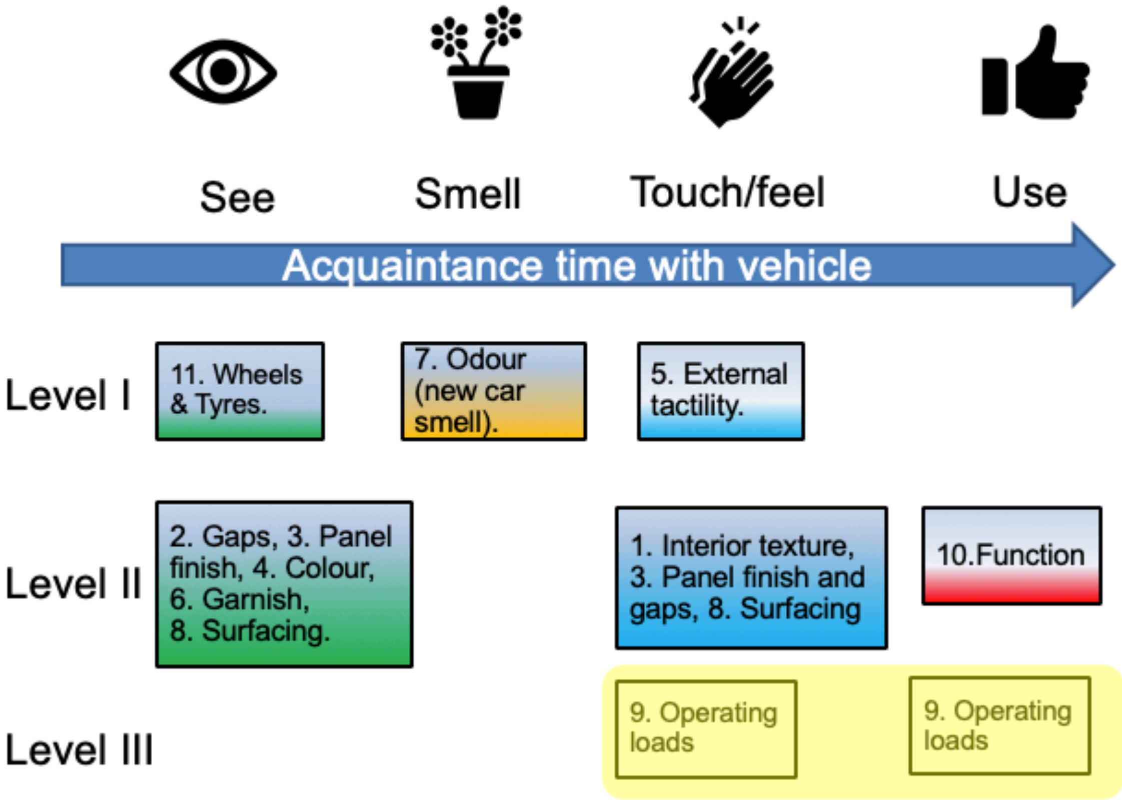


Fig. 5.16. Mental model of survey findings and time overlay.

Fig. 5.16 attempts to show how across time as a person becomes more familiar and acquainted with a vehicle, that they can pass simultaneously through level I, II and III attributes and receive sensory inputs roughly as shown, starting with visual through to inputs felt as a result of using or operating controls. The colours represent groupings as suggested by the survey. It is interesting to note the occurrence of Operating loads across two basic sense groups. Operating loads are a measurable attribute and concern the load required to operate any control, such as a door handle or light switch.

Once completed, the thesis was assessed by the originator of the research and the efficacy of this approach (in his view) will be presented as a summary of chapters 4, 5 and 6 in the Discussion chapter 7.

5.6 Conclusions

The present study focus was of the reduction and identification of a succinct number of attributes that could describe PQ. The views of PQ professionals have been examined. Attributes used were examined and the whole PQ assessment process shown to demonstrate the breadth of vehicle PQ attributes that were covered. It is difficult to see how a single list of around a dozen attributes can convey the true PQ of a vehicle.

Analysis was made of viewpoints from industry, academia and the customer. Attribute listings from each of these were compared and contrasted. Three lists were then compared and offered as a selection to the OEM's PQ department. The combined views of the PQ department were then coordinated through an ISM exercise.

This showed that it was possible to arrive at a 'best fit' of attributes (though incomplete) and when put through the ISM method, all factors were grouped logically, were related and showed (apart from Odour) a high Driving Power.

There still remains little agreement across the automotive industry about a single, valid list of attributes, as each manufacturer and commercial PQ assessment agency will have their own. An attempt has been made here to suggest an acceptable list of 11 attributes and have it validated, but even then, list ***N*** showed that it was considered to be only a 'best fit'.

The ISM study did corroborate the 11 chosen attributes and gave a relationship between them. It was a useful exercise to work with OEM experts and back up the choice of attributes, despite them being a best fit.

Having looked now at the engineer as creator of PQ and the manufacturer as purveyor of PQ attributes, the next study will examine the customer and see how the person who pays for the product views PQ. This will be the subject of the following chapter.

Before we look at the customer, a 2019 quote from Nick Bloor, the CEO of Triumph Motorcycles illustrates the PQ issues raised in this thesis, such as engineering it in, the fundamental design and emotion created by the product, with always an eye to how this would appeal to the customer.

> **"Never standing still, always pushing to get the best from ourselves, for our riders. Building iconic motorcycles that celebrate our past while embracing the future through bold design, original styling, purposeful engineering and a genuine passion for the ride.**
> **Always focused on delivering complete riding experience, creating bikes with the perfect balance of power, handling and style that totally involve the rider and bring out the best in them.**
>
> **This is our passion and our obsession.**
> **We are chasing the same thing as our riders - THE PERFECT RIDE."**
>
> Nick Bloor
> CEO Triumph Motorcycles (Bloor 2019)

This chapter was presented in paper - Pogson, I. (2016) *Human-centred design as part of measuring Automotive Perceived Quality – extending the Product Impact Model*: Design & Emotion 2016, Amsterdam.

Chapter 6 - Public Survey on the Design and Emotion of PQ

6.1 Chapter hypotheses

- Customers are the target of the manufacturer's PQ.
- Customers consume and experience PQ and this impacts purchase/choice of a product.
- Design and emotion are key aspects influencing PQ.

6.1.1 The linking thread of Kano

Kano's model has been shown link the work of Engineers in creating PQ and the OEM itself in managing PQ. Chapter 6 takes into account the final phase in the PQ creation to PQ consumption process, where the customer is central to the Kano model. The Master Features List is aimed squarely at the customer and is a prediction of what this future customer will want in a vehicle. It is something of a gamble, therefore and is influenced by many issues such as culture, fashion and increasingly social media, so is very similar to PQ and thus the Kano model is useful for illustrating the situation and for organising thought. As discussed in the previous chapter, the Kano model is governed by time and can be seen therefore as a 3-D concept through which to view PQ. Also as noted before, the model covers detail and general situations.

This last of three studies on the customer experience of PQ can again be viewed through the Kano model and so the link across the whole thesis is a strong one.

This final stage of PQ will show what customers think of the attributes or features that the Engineer has created and the OEM has developed. Again, the Kano model links this process together and can be used to examine what was intended at the start of design has been seen positively by the consumer at a detail or high level. A further discussion of PQ and Kano appears in Chapter 7.2.

6.2 Background

The previous two Chapters have dealt with studies on PQ and its creation by Engineers (Chapter 4) and management by the manufacturer (Chapter 5). This third study, again by way of an on-line survey, is the logical next step in the PQ process: the customers, users or consumers of automotive product.

Some background to the customer or public survey is given in the main Introduction to the thesis, where we discussed the influence and proven validity of PQ research particularly that conducted by researchers at Delft and Chalmers Universities. One specific aspect of such research was the combination of Design and Emotion, (respectively an attribute and an effect). These were considered to be important components of PQ and the following study contained in this Chapter addresses these.

This link of PQ to the Design and Emotion model is shown in the model following in Fig. 6.1 (linking back to Chapter 2, Fig. 2.3). So, in this Chapter we will take a closer look at the Product Impact Model (Fokkinga Hekkert, Desmet, & Özcan, 2014). Arising from the meta-data review, this model was considered a useful way of examining PQ and the interaction with the customer.

Age will be used as an independent value in this survey, see section 6.4, as the D&E model does not take any such dimension into account and it was believed to be missing from the model, but a significant factor in vehicle choice and usage.

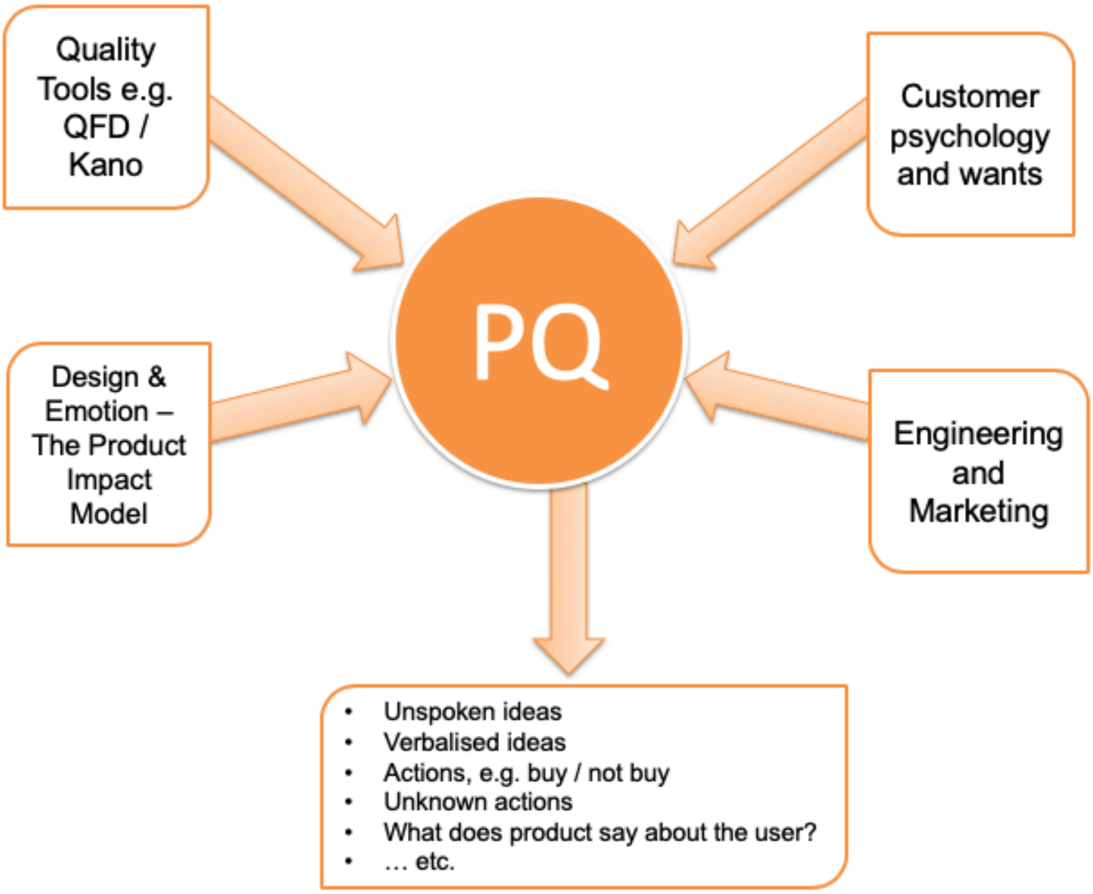


Fig. 6.1. The Product Impact Model as an input to PQ (Pogson 2016).

This amended Product Impact Model (shown as an input to PQ above in Fig. 6.1) was developed in order to gather more focused data from real customers pertaining to automotive PQ, whereby both qualitative and quantitative data may be gathered directly from individuals.

This was achieved by asking questions which were presented on a Likert scale and also ones which looked for explanations or reasons for a particular response.

The results of such a survey on design and emotion was by its very nature going to provide personalised verbatim comments, but which could then also be analysed. The research question which arises from this is focused on whether design and emotion are key components that are considered when measuring PQ.

The survey that follows contained specific questions on design and emotion linked to PQ. Also, it was understood in discussion with two of the four authors of the Product Impact Model, Pieter Desmet and Elif Özcan that no other automotive research had been conducted based upon the Model and all were supportive of this study at the D&E conference (Desmet, Özcan, & Pogson, 2016).
These attitudes towards a product are formed by many forces; one of them is the media and one of the most divisive, yet powerful opinion-formers on cars is the television personality Jeremy Clarkson. A quote from his book 'Don't stop me now' (2007) remarks of the Fiat Panda "….it feels like the fastest car I've ever driven." He follows this with "This is a car that puts a huge grin on your face", so emotion is acknowledged in this most humble form of transport (Clarkson 2007: 94). PQ is also remarked upon, with his expectations (backed up by a Top Gear survey) that it will be flimsy and fall apart, which is acknowledged as "only a feeling." At the other end of the automotive scale, the Porsche Cayenne is lambasted for its style and lack of aesthetic appeal but praised for its engine and performance (Clarkson 2007: 69). Such writers can be hugely influential opinion-formers on customers and this study will examine what these real customers think.

6.3 Introduction

Following on from the model shown above, introduced in section 2.1.2, we will now look at the final, third study of the series, where the user, or consumer – the ultimate customer is considered.

6.3.1 Study Three – The Customers

This study on design and emotion asked questions about PQ of two audiences; automotive 'novices' and the other comprising 'experts', i.e. people in the automotive industry or closely related to it. The aim was to seek novice and expert PQ views to see if they converged or were different - to look at how customers saw and articulated PQ as purchasers or just users of automotive product. The questions were based closely upon those tabled in the Product Impact Model (see Chapter 2, Fig. 2.2).

Products may be viewed as being defined by the customer, in terms of issues such as desirability, function, necessity, demand and the like, so a method of assessing their views and feelings about PQ was clearly necessary. Experience from nearly four decades of automotive manufacture and sales has presented many examples where the demand for a product has outstripped the forecast or alternatively has fallen well short. For example, the BMW Mini was planned to be built at Cowley in Oxford at 100,000 units p.a. and was introduced in 2001.

It reached 189,492 only three years later in 2004 and additional production was contracted out to NedCar in the Netherlands in 2014, along with the BMW X1 (Telegraph 2005). On the other hand, a car also produced by NedCar was the Smart Forfour, which shared its powertrain and running gear with the Mitsubishi Colt, but was phased out after only having been in production there from 2004 to 2006 due to slower than expected sales. Mitsubishi Motors owned the company at the time, having had a 50/50 Joint Venture (JV) with Volvo until 2001 (VDL 2018). In comparison, the Ford Capri was another surprise seller, shifting nearly 1.9 million units between 1968 and 1986 (Braithwaite-Smith 2019).

Another example from the automotive world centres around the Rover 400, launched in May 1995. As the RAC's Johnathan Crouch recorded ten years later in 2005, "…. despite Rover's claims, this was not a Mondeo-sized car. Think Escort and you'll be pleasantly surprised to find the Rover a little larger than you expect. It's a sound family hatchback all-rounder".

The manufacturer's aspirations were laid out in the web-site article as being "executed with a touch more class (*than its competitors*)" (Crouch 2017). The perception being created by Rover was something better than a Ford or Vauxhall of the time, and even better than the Honda Civic upon which it was based. However, despite intentions, the physical dimensions (length especially) of the car were less than the cars against which it was pitched and priced, e.g. the Ford Mondeo (see Fig. 6.2), so the customer perception was that it was smaller than the Ford.

Attribute/dimension	Rover 400	Ford Mondeo
Length	4,320mm	4,537mm
Width	1,910mm	1,925mm
Height	1,390mm	1,372mm
Wheelbase	2,620mm	2,704mm

Fig. 6.2. Rover 400 hatchback 1995 – 2000 and Ford Mondeo Hatchback 1993 – 2000 (Crouch 2017)

In a regularly repeated cycle, Marketing’s aspirations for a volume manufacturer (i.e. around one million units p.a.) fell short of planning and capacity. This happened with the Rover 400, the 600, 800 and latterly before the Company’s demise, the Rover V8 (Adams 2018). The PQ of the Rover 400 was planned to be good, but the element of value for money was not; alongside a Mondeo, it was a smaller (shorter and narrower, albeit taller) car and seen as such.
The perception was that it did not present itself as a size-for-size proper competitor for the Ford product and was somewhere in between a Ford Focus and a Mondeo, yet it was priced nearer to the larger car, the Mondeo (Crouch 2017). Crouch did go on to say however of the Rover that “….it has a class missing from most of the volume-produced competition.” This is a clear reference to PQ, yet the car only scores a combined total of 57 out of 100 in the RAC scoring. One of the lowest figures was for “Build” (Quality), 40 out of 100. His comment on the Ford Mondeo against which it was pitched included “…this is the most enjoyable driver's car the company has ever made” and he makes direct reference to high build quality, in contrast to the RAC scores. Therefore, this would suggest that the customer has to be the centre of the PQ journey, despite being at the end of the process already discussed, so as to avoid mistakes like the Rover 400 and create success stories such as the Ford Mondeo.

6.3.2 Why the public?

The general public ultimately represent the customer in the use, or purchase of a vehicle. Their views are those of real, paying customers and all of the participants selected or targeted in the survey were owners and/or regular users of automotive product. A large number of researchers survey and interview the public and some were mentioned in Chapter 3, such as Yee and San's work (2011).

6.3.3 Research questions

The foregoing sections have looked at a few examples of how the sales of a product are influenced by PQ and that design, emotion and PQ are closely intertwined so a number of survey questions were designed to investigate this relationship. The meta-data (Chapter 3) showed evidence of how in the literature the three concepts of PQ, design and emotion could be related and strong influences upon purchase of product, culminating in the model linking these in Fig. 6.1.

Therefore, the research question here is to prove the validity of Fig.6.1 and the link of PQ, design and emotion and how significant this link was to the all-important purchase of a product, i.e. what PQ means to the customer/user stakeholder community.

6.3.4 Age as a factor

In this survey, age will be used as a factor, as the usage of a vehicle can change overtime as job and family needs evolve.

Ages will be grouped into 18 to 25, 26 to 35, 36 to 45, 46 to 55, 56 to 65 and over 65, although some respondents preferred not to divulge their ages.

6.4 Method

The method used in this final study was again a survey. The reasons for this choice are:

- A survey had been successfully used in Chapter 4.
- Verbatims - words - were thought to be key to a greater understanding of PQ from a Customer point of view.
- Surveys are easy to set up and administer, with a good spread cost-effectively across a wide range of people.
- This researcher is comfortable with a survey.
- The modern world is used to on-line surveys.

Other techniques could have been used, such as structured face-to-face interviews of the public. These were attempted at a motor show, but were not well received by the interviewees. Neither was the researcher comfortable. Structured interviews were however successfully used in the pilot stage, discussed in section 6.3.1.1.

6.4.1 Survey Design

The need for a survey of customers was to complete the journey of PQ from its creation by Engineers in Chapter 4 through its management and development by the manufacturer/OEM in Chapter 5 to its consumption by the customer/user. Useful data had been found from the two previous surveys to support the aim of this research, which was to find an improved measure and definition for PQ. So, to leave the customer out would have been remiss. A survey modelled upon the Product Impact Model discussed in Chapter 2, Fig. 2.3 was considered a useful way of interrogating and organising customer views on PQ. In the first instance, an Excel version of the Model was created and tested on 12 friends and family, with the researcher sitting with the respondent to assist with understanding. This was developed as described following in 6.3.1.1 and tested on 6 automotive SMEs, then turned into a BoS (Bristol on-line Survey) and described in 6.3.3.

6.4.1.1 Pilot survey in Excel

The survey was created around the Product Impact Model as previously highlighted in Fig. 6.1, taking its questions almost directly from the Model. This was then modified and annotated to show where the principal design and emotion questions 6 to 12 originated in the Model and became part of the survey, whereby questions 1 to 4 were demographic in nature, with 5 asking about automotive interests (see Fig. 6.4 in section 6.3.3). The pilot phase took learning from friends and family, who needed more explanation in each cell and then was conducted with six automotive SMEs, as they were available on a daily basis and was shown as a printed form, in face-to-face interviews using the format shown in Fig. 6.3.

<table>
<tr><td rowspan="4">OVERALL EFFECT</td><td colspan="3">QUALITY of LIFE and SOCIETY</td></tr>
<tr><td colspan="3">Does the product contribute to pleaure, personal significance and virtue?</td></tr>
<tr><td>BEHAVIOUR (Doing) [Does it make one do anything different?]</td><td>EXPERIENCE (Feeling) [Functional and affective)</td><td>ATTITUDE (Seeing) [Any new view of self or others through use of product]</td></tr>
<tr><td>Does the product stimulate, influence or facilitate any new or different behaviour due to use?</td><td>What does use of the product evoke? What does it make possible?</td><td>Does the product help perceive, realise or appreciate something?</td></tr>
<tr><td rowspan="4">INTERACTION</td><td>AESTHETICS</td><td>EMOTIONS (Evoked by product)</td><td>PRODUCT MEANING (Descriptors)</td></tr>
<tr><td>Does the product gratify or offend?</td><td>Disgust or desire from use of product?</td><td>What nouns and adjectives are conjoured up by use of the product?</td></tr>
<tr><td>HUMAN-PRODUCT INTERACTION (What one does with product)</td><td colspan="2">Perception of product, physically interacting with it.</td></tr>
<tr><td>PRODUCT PROPERTIES (Spec.)</td><td colspan="2">What is its physical description, size, shape, functionality and technology. The important bits to you.</td></tr>
</table>

Fig. 6.3 Pilot survey questions with explanations as to what information was sought (Fokkinga, *et al.* 2014, annotated by Pogson 2016).

6.4.1.2 Survey Design – final

Lessons learned from the pilot Excel-only survey were built into the final on-line survey, with questions added to ask why certain words had been used or choices made and ensure the information sought as in Fig. 6.3 was captured on-line.

Learning from the pilot phase included adding extra questions to elicit qualitative data as to quite why people had replied the way they did. The final survey was designed to be compliant with Coventry University Ethical guidelines and as such, Bristol On-line (now Online Surveys) was selected as a tool. Ethics approval was given via Coventry University project number P50903. The available BoS survey tools were used.

With a Bristol on-line survey, the respondent can choose to complete the questions or not in their own time. The on-line survey also allowed for some targeting at people who would fit either categories of customer, i.e. expert and novice.

6.4.2 Participants

This survey was conducted with 113 respondents via an opportunistic sampling approach – thus no specific group of participants were targeted, (apart from experts and novices) and the survey was simply distributed amongst family/friends etc. Age and gender details are revealed in the graph following in the Chapter Appendix A6.1. None were participants included in the first study (as this researcher was now working in a different company to when the first survey was made). The survey was split, with the same questions asked, into two separate groups: those with some engineering or automotive knowledge and/or experience (termed here as 'experts') and those with little or none (the 'novices'). This is a selection criterion utilised in response to research which suggested that there should be a difference between expert and novice groups(Johnson, Mervis 1997). The age profile of the participants was a normal distribution with a mean of 46.56 (SD 8.6) years.

6.4.3 Materials

The questions posed during the final Bristol on-line Survey can be found in Appendix A6.2. The category label for the questions within the survey are summarised in Table 6.1 following.

Table 6.1. The structure of the questionnaire (adapted from Fokkinga *et al.* 2014), with questions 1 to 5 added.

Question number	**Subject of question**	
1 to 4	Participants' backgrounds and details not included in the initial Product Impact Model (Age, gender, education, cultural roots). The extra questions over and above those shown in Fig. 5.3.	The responses were categorical statements or numbers.
5	Automotive interests – are you a petrol head?	
6	Type of vehicle and some technical details of it.	These responses were phrases or words.
7	The use(s) made of the vehicle.	
8	The aesthetics of the vehicle.	
9	The emotions evoked by use of the vehicle.	
10	The meaning of the vehicle; an adjective used to describe it.	
11	Any new behavioural trends associated with using the product.	
12	The feelings about the vehicle's function and its affect.	
13	Examined the user's attitude to the vehicle.	
14	Considered the effect of usage of the product on the wider society.	

Fig. 6.4 below shows how the questions in Table 1 are related to the original Product Impact Model.

<table>
<tr><td rowspan="4">OVERALL EFFECT</td><td colspan="3">QUALITY of LIFE and SOCIETY</td></tr>
<tr><td colspan="3">14</td></tr>
<tr><td>BEHAVIOUR (Doing) [Does it make one do anything different?]</td><td>EXPERIENCE (Feeling) [Functional and affective)</td><td>ATTITUDE (Seeing) [Any new view of self or others through use of product]</td></tr>
<tr><td>11</td><td>12</td><td>13</td></tr>
<tr><td rowspan="4">INTERACTION</td><td>AESTHETICS</td><td>EMOTIONS (Evoked by product)</td><td>PRODUCT MEANING (Descriptors)</td></tr>
<tr><td>8</td><td>9</td><td>10</td></tr>
<tr><td>HUMAN-PRODUCT INTERACTION (What one does with product)</td><td colspan="2">7</td></tr>
<tr><td>PRODUCT PROPERTIES (Spec.)</td><td colspan="2">6</td></tr>
</table>

Fig. 6.4. Product Impact Survey and corresponding survey question numbers(Questions 1 – 5 are not shown but are the added base demographic details). (Fokkinga, S., Hekkert, P., Desmet, P., Özcan, E. 2014).

6.4.4 Procedure

The Survey had been piloted by using the Product Impact Model, but with additional questions 1 to 5 giving some idea of educational, cultural and other background information that was considered missing from the model. In the pilot Excel sheet, each cell had an explanation in the form of a comment or note embedded in the format. This was intended to assist the respondent (see Appendix A6.3). This was tested by a limited run on-line only circulated within the research team and was refined further until it was considered suitable for full distribution.

The on-line format allowed extra qualitative questions to be presented and explanation sought from respondents as to why they had replied in a certain way. The full list of final questions used on-line is also shown in Appendix A6.4. The survey was launched on 20th March 2017 and ran until 3rd April 2017.

The survey was purposefully sent to those who could be classed as novices (i.e. do not work in the automotive or related sector) and those who met the criteria for experts (i.e. an Automotive Engineer, employee of an OEM with over 5 years of automotive experience and service, or someone who clearly demonstrated a knowledge of the industry). This was achieved via personal contacts for the experts, whose responses validated the grouping through their use of technical detail. Novices were targeted by using people who were personal contacts and asking these to pass the survey on to similar non-expert or non-technical people.

6.5 Results

The data, certainly from questions 6 onwards was mostly non-parametric, as many of the questions were in the form of Likert scales. The results of such non-parametric data were collated and examined as one set of data, having been originally sent as two identical surveys to experts and novices. There was little value in keeping them separate, although some results are shown below for comparison. For example, question 2 looked at the educational backgrounds of both groups and are shown below in Figs 6.5 and 6.6.

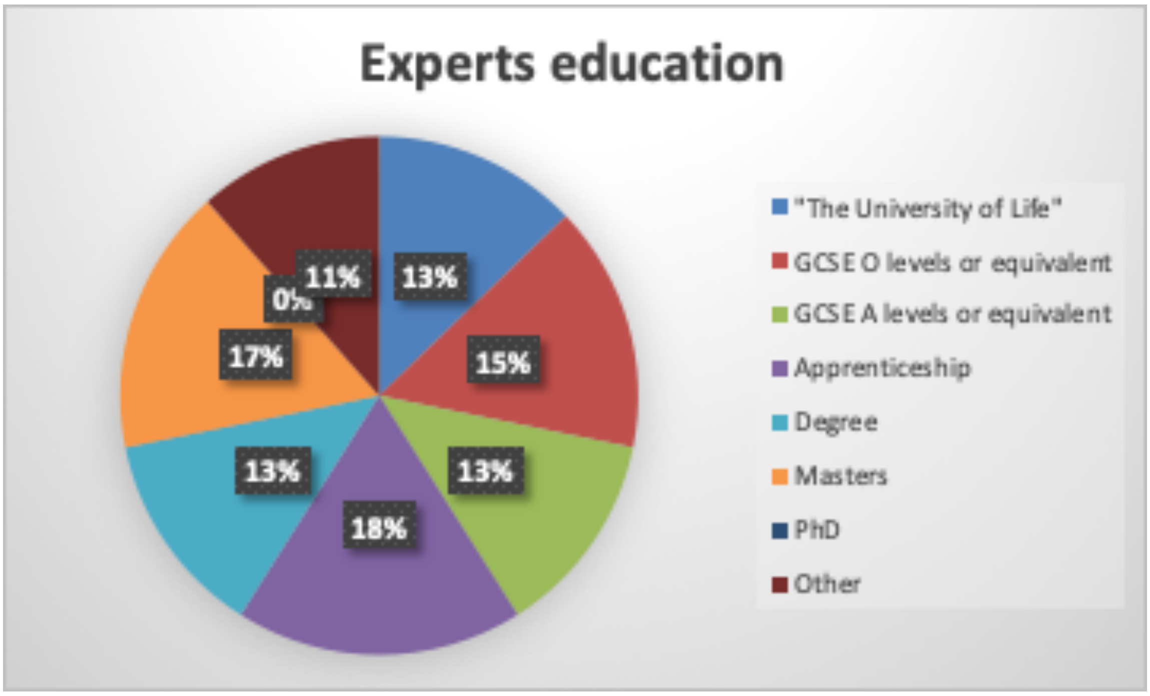


Fig. 6.5. Educational background of 'Experts'.

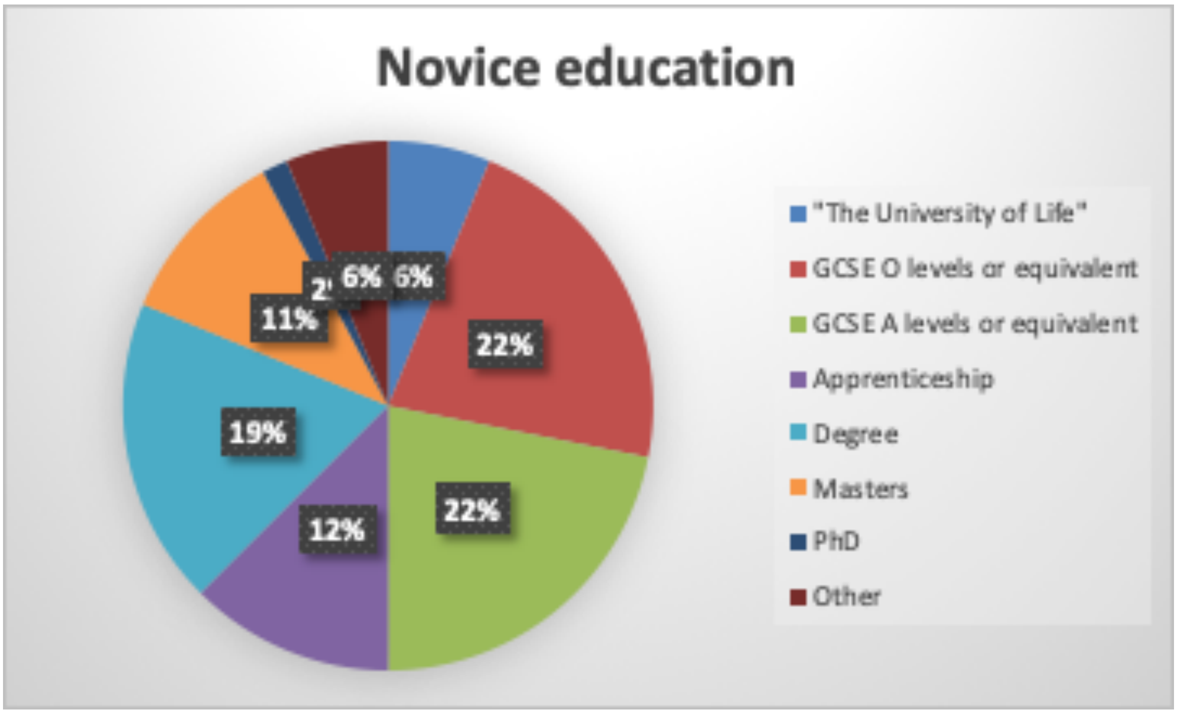


Fig. 6.6. Educational background of 'Novices'.

All of the suitable (such as Likert scale, age, education) responses, etc., are presented as two example screenshots shown in Appendices A6.5 and A6.6. with samples of coding and responses used in the survey data analysis.

6.5.1 Descriptive analysis

Moving onto the core questions of design and aesthetics, the figures following show the responses about design from the survey, split into experts and novices, gain for comparison, as there were some differences.

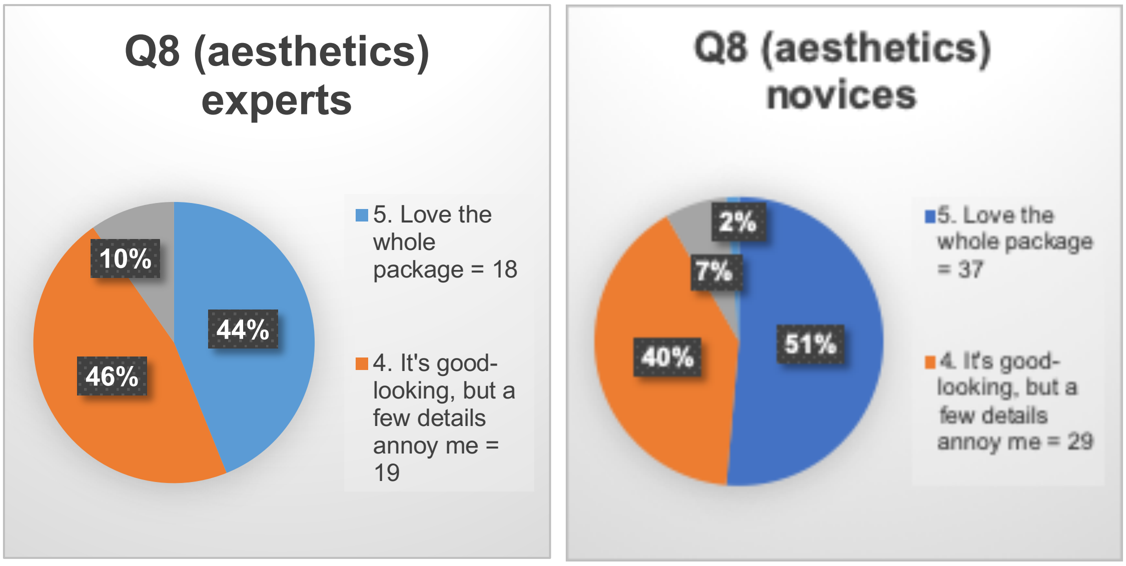


Fig. 6.7. Sample responses to Q.8 from experts and novices – key below

5.	Love the whole package
4.	It's good-looking, but a few details annoy me
3.	The vehicle has neither appeal, nor does it annoy me
2.	In my view, there are just too many annoying details
1.	This thing is ugly

Views on aesthetics are shown in the above chart, Fig. 6.7, with most respondents having positive feelings towards their vehicles. (Only the most significant statistics are shown for ease of reading). The separated views in Fig. 6.7 show very little difference, so Fig. 6.8 following shows them combined.

It could be argued that an interest in things automotive (Question 5), could skew the readings taken from this survey, so the interests of all participants was assessed, not just the experts. Automotive views were important here and results showed that for the population selected, there were a significant number who were interested in vehicles.

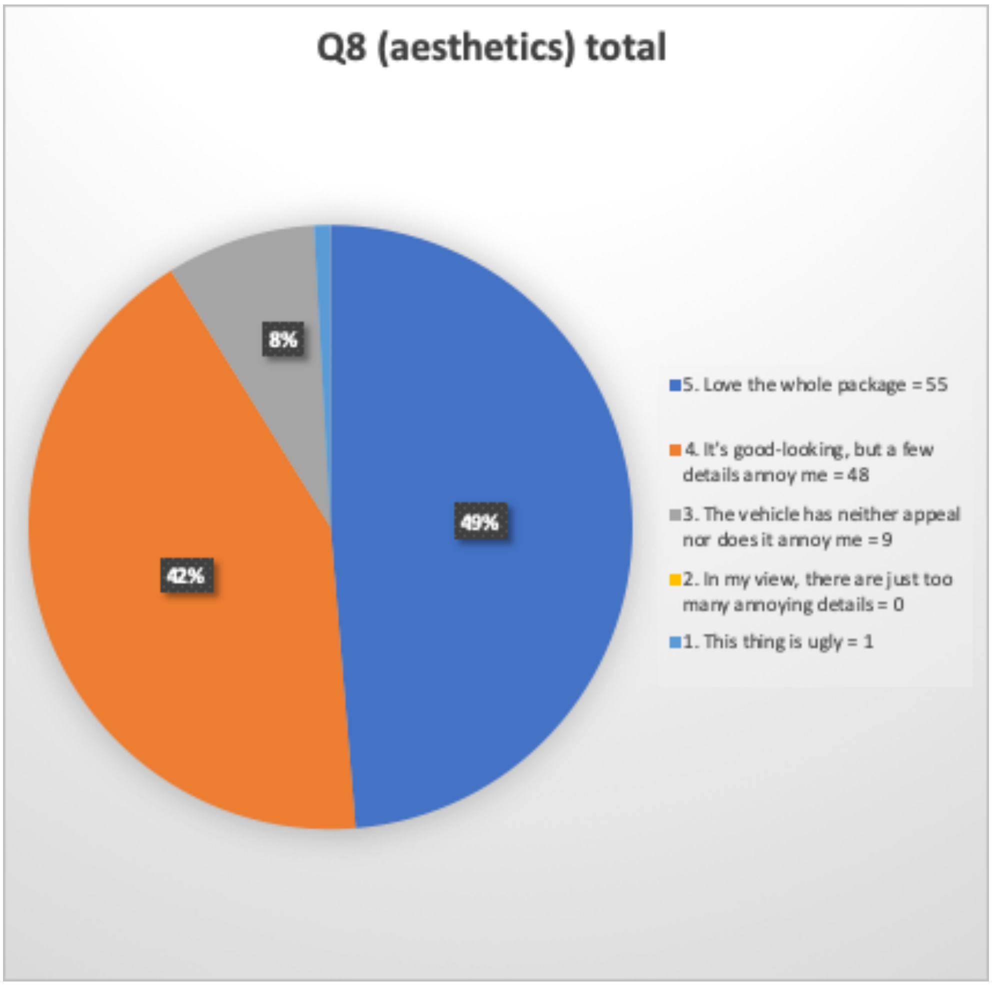


Fig. 6.8. Aesthetics views of combined groups

It can be seen that some key words and attributes arise, as shown on the column headings below in Table 6.2. Further examination of the qualitative data was used to examine which of these was the more common.

The following table used Thematic Analysis to show as a simple count of those words used to describe the responses to Questions 8 and 9.

The themes selected were driven by grouping the words used under appropriate headings, which were themselves driven by the questions in the Impact Model.

The table following shows a variety of words used and it could be argued that some belong in other columns or in two or more, but the most frequently used words would still be those shown.

Table 6.2 shows an interesting variety of words used across the themes against the question on the behaviour stimulated by the use or ownership/use of the vehicle. Functional shows a very low count, with speed and dynamics well represented. The table shows a combination of questions 10, an adjective to describe the vehicle and question 11, on what behaviour is stimulated by the use of the automobile. It can be seen that the words in black are from question 10 and those from 11 are in red. Where green words are shown, these are the ones common to each question.

Table 6.2. Combined responses to Question 10, searching for an adjective to describe the chosen vehicle and 11, behaviour stimulated by it.

Word count for Questions 10 on adjective to describe vehicle and 11 (red) behaviour stimulation Common words in green							
Design		Emotion		Speed	Dynamics	Economy	Function
8 space/spacious	1 equipped	9 comfort/able	1 joy	15 quick/ly/er	12 fun	4 economical	9 reliable
6 looks	1 fancy	10 enjoy/s, enjoyment	1 perfection	9 slow	16 relaxed	3 responsible/y	3 functional
5 practical	1 flexibility	5 pleasure/able	1 personality	5 power/ful	4 confident/ly	1 efficient	3 useful
4 versatile	1 friendly	5 freedom/independenc	1 precious	4 accelerate	4 ride	1 frugal	2 dependable
3 old	1 glove	2 fantastic	1 privacy	4 performance	2 handles	1 green	1 adaptable
2 attractive	1 looking	2 good	1 prestige	3 exhilarating	2 smooth	1 thirsty	1 adequate
2 solid	1 lovely	2 happy	1 purpose	3 speed	1 accomplished	1 consumption	1 insurance
2 style	1 luxurious	2 smile	1 rare	3 fast/faster	1 apprehensive	1 efficiency	1 ownership
1 arresting	1 stunning	1 calm	1 reflection	2 nippy	1 astounding	1 uneconomical	1 talented
1 bright	1 sumptuous	1 boring	1 responsible	2 response/ive	1 capable		
1 chariot	1 pleasant	1 character	1 security	2 sports, sportie	1 competent		
1 clean	1 smart	1 convivial	1 special	1 aggressively	1 corner		
1 compact	1 sexy	1 emotion	1 ultimate	1 acceleration	1 darting		
1 complete	1 sleek	1 escape	1 uncool	1 cruiser	1 demanding		
1 contemporary	1 small	1 excite	1 unique	1 noise	1 donkey		
1 cute	1 pretty	1 executive	1 well	1 racey	1 dynamic		
1 conservative		1 important	1 wonder	1 spirited	1 enthused		
		1 impressive	1 wow		1 exciting		
					1 involving		
					1 rewarding		
					1 safe		
					1 sporting		
					1 stealthy		
					1 thrilling		
					1 transport		
					1 troublesome		
58 words total		65 words total		58 words total	60 words total	14 words total	22 words total

Table 6.2 shows a good deal of common words between the two questions, with a healthy showing for Design and Emotion, an unexpectedly high count under Speed and Dynamics, with much fewer under Economy and Function.

As opposed to lists and tables, word clouds were considered to be a useful graphic to show some of the words used by respondents. As the subject here is mostly described by verbatim comments, the following word clouds show pictorially what words were employed by the respondents for two of the questions posed, 9 and 10. In these cases, the Expert responses are charted. Words used more frequently are shown in larger font.

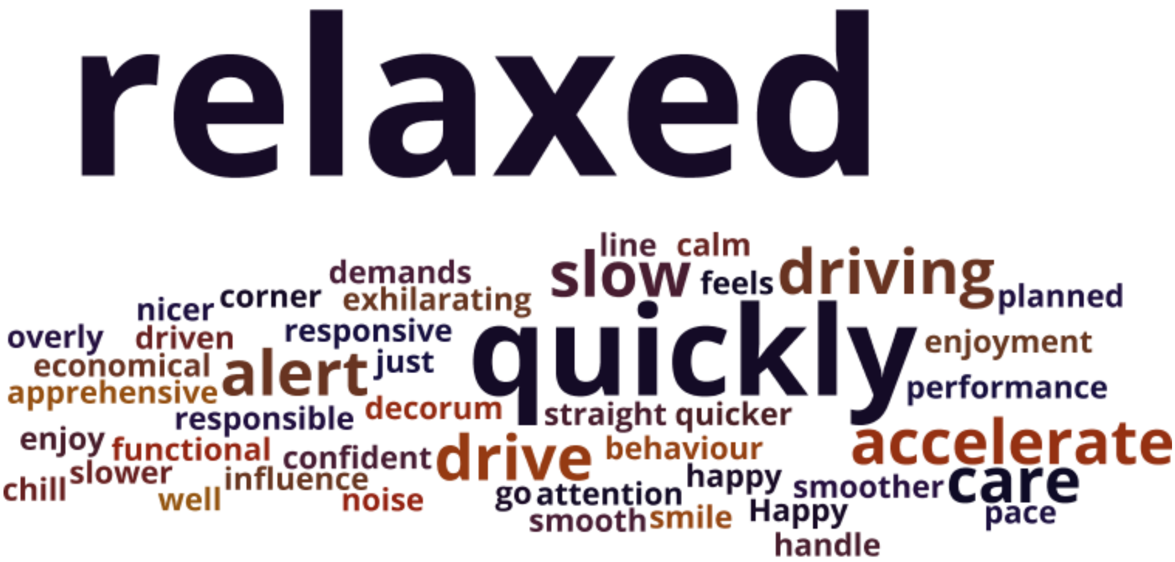


Fig. 6.9 Word cloud for expert responses to Question 9

Fig. 6.10. Word cloud for novice responses to question 9

The contrast between the two clouds (answering the same question – Q9) shows some more technical words and interests in the 'experts' cloud in Fig. 6.9 with more emphasis on dynamics/performance than the 'novices' in Fig. 6.10,with words like 'responsive', 'accelerate', 'handle' and 'noise'. Both clouds show 'relaxing' as a strong favourite word to use, with also some emphasis on aesthetics or design. There are also more emotive words used by the novices than experts, such as 'feel', 'apprehension', 'excitement' and 'love'. The impression from Figs. 6.9 and 10 shows that design and emotion are, along with speed-related words, far more frequently used words than any others. However, the word "quality" only appears once in the verbatims and there is a lack of direct reference to this aspect.

Question 13, which enquires of the respondent their attitude to the vehicle, does not lend itself to analysis of replies by word count, as it is phrases rather than single words that convey meaning.

Some verbatim examples are set out below, with significant phrases underlined:

1. "The benefits of two-wheeled transportation over four."
2. "A sense of belonging."
3. "I do appreciate it and perceive the quality, but if it lets me down then it will be replaced."
4. "It is simply that it is the best value for money in the bracket of vehicles that meet my needs without offending my sense of visual aesthetics."
5. "It makes me feel that driving is not just about getting somewhere no matter what."

Finally, question 14 looks for some relationship with the rest of the world in the respondent's use of the vehicle. Again, a simple word count is not appropriate, and some sample verbatim responses are recorded below:

1. "Enjoyable because it's efficient, relaxing and quality made."
2. "A necessary evil..." (This was a phrase suggested in the question).
3. "It's a VW, I have been lied to, but I am not sure I am bothered - have had the engine fixed so a good person. Will I have another diesel? Will see what the government do re tax, but press make me feel I shouldn't." (A reference to the VW scandal where VW AG lied about emissions testing, (Leggett 2018).
4. "Necessary for the commute; like the fridge, it does the job."
5. "It is a comfortable, well built, reliable and attractive workhorse - much loved."

In the responses to questions 13 and 14 above, some key words and phrases were underlined. Many of these contribute to the Design and Emotion slant of this chapter.

Response number 3 shows an influence of the media on what people are to think of their cars.

In the wake of the VW scandal, other manufacturers have come under scrutiny and 2017 sales of diesel cars in Europe slowed significantly by 3.7% compared to 2016, with some manufacturing plants on short time (Demandt 2018, Griffiths 2018).

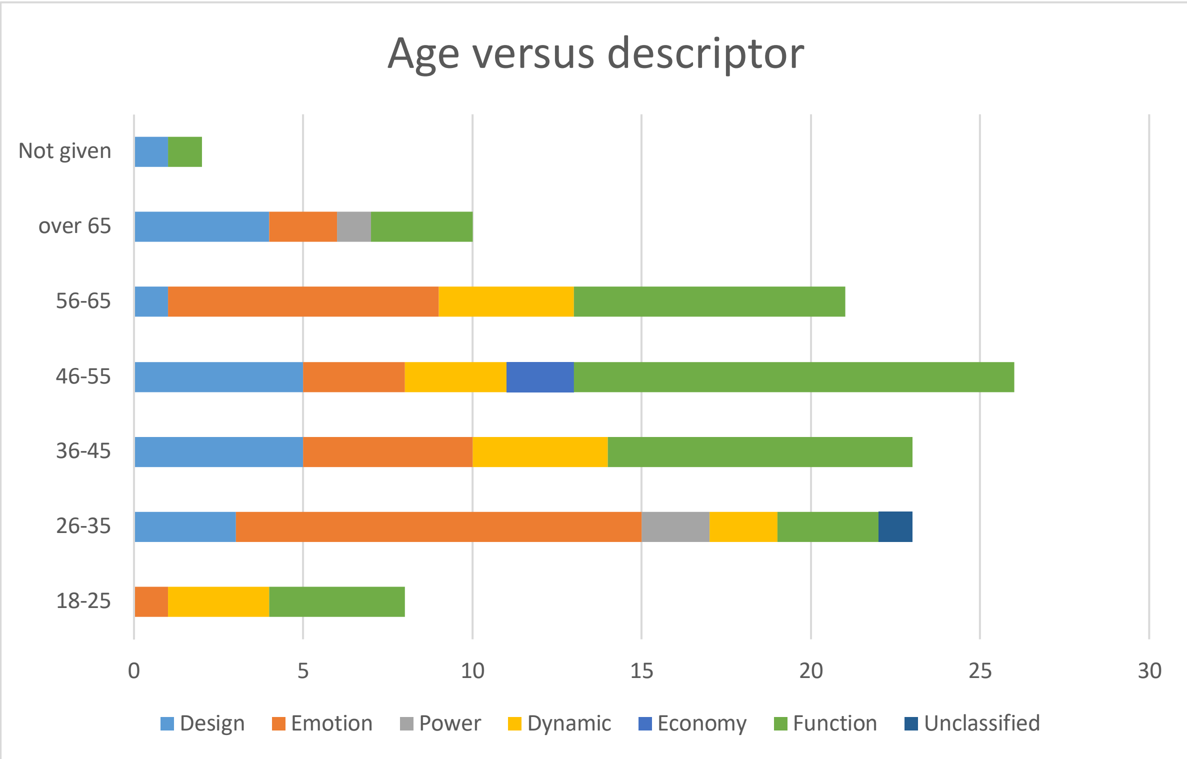


Fig. 6.11. Age ranges against most used words

Fig. 6.11 looks at the raw data for each of the six most used words (plus 'unclassified', i.e. those words that did not fall into the main groups), uncorrected for the number of participants within the age ranges. Correcting for this does not give a clearer picture.

6.5.2 Inferential analysis

Following on from the descriptive analysis in the previous section, we shall now consider what can be inferred from the data by using statistical comparisons.

As we do not have normal distributions of words, we shall look for associations and differences via Chi-squared and Kruskal Wallis (KW) tests. KW is a non-parametric comparison, seeking for differences in three or more groups, where the data is not normally distributed.

In Chi-squared tests made between age plotted against Design, Emotion and Function, the null hypothesis suggests that there is no relationship between these words.

This is not rejected, as the value of Chi-squared (28.00) has asymptotic significance figures of $p = 0.26$, 0.227 and 0.243 respectively. This sample implies that there is no relation between age and any of these three factors. Other uses of Chi-squared analysis were not successful and as this was non-parametric analysis, it was considered useful to create some categories of responses, code them and employ a KW test to look for any differences which is suitable where a choice on 5-point opinion scales is used. This was applied using an H value (KW factor) and 2 / 113 degrees of freedom. Significant values were shown against all survey questions – see Appendix 6.7.

A significant difference was found against the Aesthetics factor (Q8), where ($H(2) = 12.167$, $p = 0.02$), for the Attitude effect, so aesthetics clearly has an effect on customers. There was little difference between other factors, many showing a p-value of less than 0.001, so a relationship exists with all.

Considering Emotion evoked by use as a factor, ($H(2) = 8.094$, $p = 0.017$) was highest for the attitude created in the user. All others showed a relationship, with zero or near-zero p values.

Looking at Ergonomics scores (part of Q8), ($H(2) = 5.574$, $p = 0.062$), so a relationship was shown, versus the attitude created in the user.

Considering Colour as a factor, (part of Q8), ($H(2) = 12.226$, $p = 0.02$), a pleasing colour affects the experience, or what the product means to the user.

Looking at the Petrol Head factor, (Q5), ($H(2) = 6.260$, $p = 0.012$) all except the emotions evoked by the product showed no relationship.

Looking at education (Q3) as a factor, ($H(2) = 7.601$, $p = 0.022$) the adjectives used to describe the product had a logical link.

For the factor of age ranges, the strongest relationship was with Attitude (Q13), ($H(2) = 12.682$, $p = 0.048$). All other factors showed p-values of 0.247 to 0.966.

6.6 Discussion

The purpose of these three surveys, of which this is the last, was to analyse the cycle of a product from its creation to consumption. We have already seen in Study 1 (Chapter 4) that the Design Engineers create PQ.

We followed this in Chapter 5 with the view of what happens in an OEM where PQ is managed and developed. This chapter looked at the final stage of PQ where it is in the hands of the customer and is consumed, experienced and the product, a vehicle, is lived with and used.

A different type of data collection method was used for this study that focussed on users, whereby an open access on-line survey (which gave potentially the widest distribution) was sent out to participants who used and/or owned vehicles. This survey was designed to build on a well-developed model which had not been specifically intended for automotive use but had been created by experts from the Design Society (Hout 2018). The now extended model was a good fit with the research topic and its use was endorsed and indeed signed by the creators (Design & Emotion 2016).

Extending the model meant gathering some demographic details for those surveyed, so that some analysis could be performed against an independent variable, which in this case was age.

As shown earlier in Table 6.1, questions 1 to 4 were demographic in nature and from 5 to 7, the responses were mainly simple categorical statements or numbers, whereas from 7 onwards, the responses were qualitative phrases.

Ages across the survey showed a reasonable representation across the lifetime of a driving customer and the charting of qualifications for the split of novices and experts showed a not surprising slightly greater spread of higher qualifications amongst the experts, but not such a great difference. Very little difference was seen in the same questions between the two groups. Aesthetics are an essential PQ ingredient as shown in Fig. 6.5 earlier and may affect purchasing influences (Stylidis, Wickman and Söderberg 2015). Design clearly is part of the aesthetic ingredient to PQ.

The very fact that the basic model upon which the survey was founded arose out of the work of the Design Society and that the words “design” or “aesthetics” appear so frequently in the research material shows how important this visual aspect is. In order to further validate this statement, the appreciation or otherwise of the vehicle aesthetics, with most respondents liking their chosen vehicle, is shown in Fig. 6.8.

These results showed that there are a great many words used by customers to describe what PQ means to them. Some, like “spacious”, “fun” “enjoy”, “quick”, “relax/relaxed” and “functional” are used regularly.

The over-arching themes of Design, Emotion, Dynamics, Economy and Function provide a framework for these words to hang from and be related.

As the aim of this research and this study is to come to a better understanding of and measure for PQ, then it is clear that aesthetics figures highly but there are many other contributory factors. So, it would appear from this descriptive work that Design and Emotion are absolutely fundamental to customers. Functional issues have also been seen to be important. The word cloud also shows this result more graphically in Figs. 6.9 and 10.

By plotting the words used against ages, as in Fig. 6.8, it can be seen that the components of PQ most expressed by the buying or using public are attributes such as function, design and emotion.

Economy, for example, features only occasionally in these results. It is also interesting how the emphasis on each attribute changes with the age range.

The survey data had shown that those starting off in their driving career look for mostly dynamic and function, so a good handling car which does the job and only a small component of emotion (Gibson 2018, Thomas 2017). At the other end of the age range, design and function fare almost equally, as shown in the graphs in the Chapter Appendix A6.8, with some power required by customers and a little emotion shown, as illustrated in Fig. 6.12 (Gorzelany 2018).

Fig. 6.12. Dodge Charger, number 3 in top 20 cars for senior drivers, Forbes magazine (Gorzelany 2018).

Fig. 6.12 shows some interesting comments in the panel below the image, whose inclusion shows the manufacturer is aiming to appeal to the older driver, which is unusual for a car with sporty pretensions, but this does support the survey findings.

The statements in some of the survey verbatims show the participants' expressions or views as customers and/or vehicle users.

Without any form of coercion or prompting towards quality or PQ, only 3 of 13 statements mention quality and 2 VFM (Value for Money).

Perceived quality sees one mention, although other researchers see the link between PQ and Perceived Value (PV) (Newman and Dhar 2014, Afsar 2014, Fernandes and Alves 2012).

Although this study focuses on the customer and looking to them for a definition of PQ, states of enjoyment and pleasurable feelings are highlighted by the verbatims, which are PQ-related. The words used by participants in the survey responses shows that positive emotional affect, i.e. something that makes a difference to or influences customers, is experienced by all users/drivers in all age ranges.

As discussed in the study on Engineers creating PQ in Chapter 4, this emotive connection is also that which manufacturers wish to create with their products to differentiate and sell them.

Younger customers are seen to be more interested in practicality and function, as arguably that is what they can best afford. The emotional effect, i.e. a change produced, or outcome may be that they choose one vehicle over another.

The thread through this thesis is how can PQ be assessed or measured, as it is a vital part of the purchasing outcome (see Fig. 2.14) and these two issues of design and emotion have been shown to be central to this measurement (Demirbilek et al. 2004, Desmet and Schifferstein 2012).

Across all the inferential statistical tests, the results show that there is a strong relationship across all questions with many factors such as Aesthetics, Emotion, Ergonomics, which reinforces the premise of this survey in particular. Those factors such as Colour, ‘Petrol Head’, Education and Age Range only affected one question each.

In this search, we have now come to customers/users at the end of the PQ consumption process, from its creation by Engineers in Chapter 4, the management of PQ by the OEM in Chapter 5 and the research question specific to this chapter - to investigate what PQ meant to the customer/user stakeholder community.

Across Chapters 4 and 5 and now 6, we have looked at the whole PQ process and found some useful descriptors of PQ, views upon how it is created, plus some key words used and attributes. These surveys have come some way to creating an improved PQ measure.

Finally, and more immediately, in order to try and make an enhanced sense of these customer/user survey results, we will consider building up a mental model, by studying the words used by the customers themselves.

6.6.1 Building up to a Mental Model for the customer survey results

This survey is summarised in the development of a model shown in Fig. 6.13.

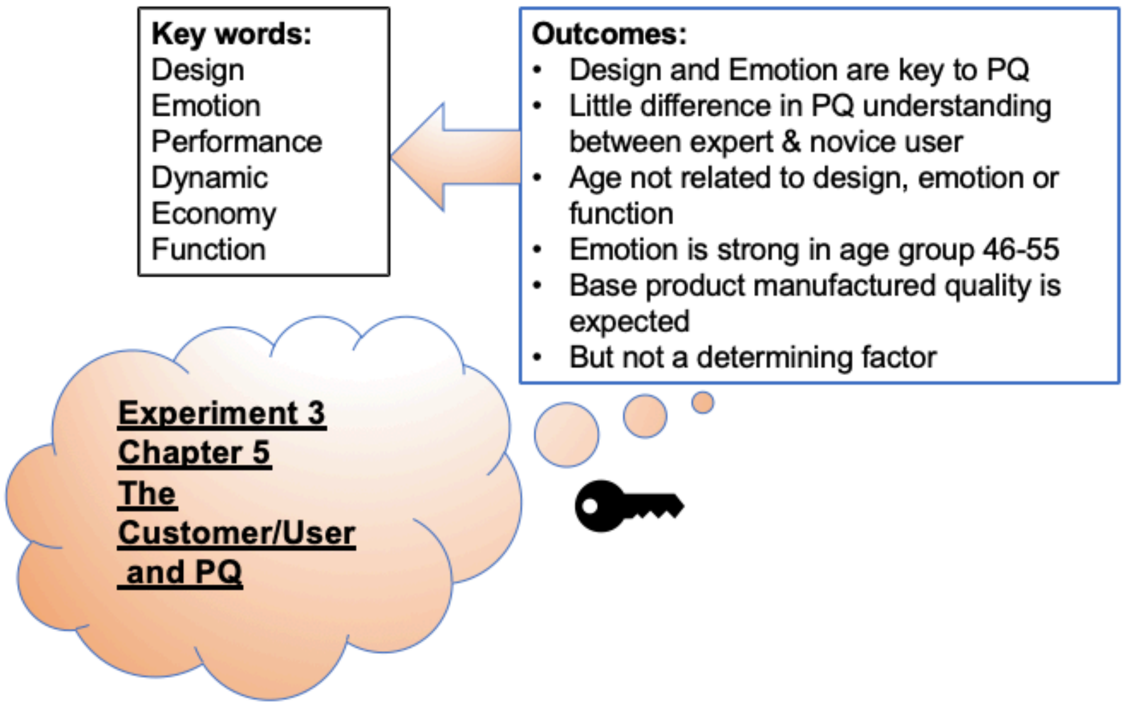


Fig. 6.13 Summary of key words and outcomes for the survey results

Fig. 6.13 shows the start of a mental model for this survey and summarises what has been seen in the study, with the crucial issues of design and emotion showing strongly and the relation of age to some factors not being related.

Key words again are design and emotion, with function, dynamic and performance being represented. Fig. 6.11and Table 6.2 showed the frequency of times certain words were mentioned in the responses. The x-axis in Fig. 6.11 shows the size of the tally and it is clear that the two principal thrusts of this Chapter, Design and Emotion, are higher by count than any of the other four words counted.

Looking in more detail at age range and replies, Design itself shows a stronger response for the over-65 ages, which was not expected, but high for 36-45, which would fit with common expectations in the industry. Emotion shows a low count in early years, rising to a high count in 46-55. Performance is high in the 36-45 range, but low elsewhere.

Dynamic is high in early ages and again at 56-65. Economy only features high in 46-55. Function appears high in all but 26-35 and over 65.

It has been discussed in previous research that there is a difference between the two sets of customers, the experts and novices, but little evidence has been shown to either support or disprove the proposition. Indeed, little difference was shown in the results. In this case and with these questions, examining the descriptive data indicated that there does not seem to be much difference in their responses, (see Chapter Appendix 6, Figs. A6.1 and A6.2) so they were combined into one voice and set of data, which agrees with previous research on splitting experts and novices on automotive quality issues (Ersal *et al*. 2011, Golder, Mitra and Moorman 2012). Asymptotic significance figures of 0.26, 0.227 and 0.243 respectively implied that there is no relation between age and design, emotion or function. A development to a mental model of the summary in Fig. 6.13 is shown in Fig. 6.14 following, which takes into account the key words used and their frequency.

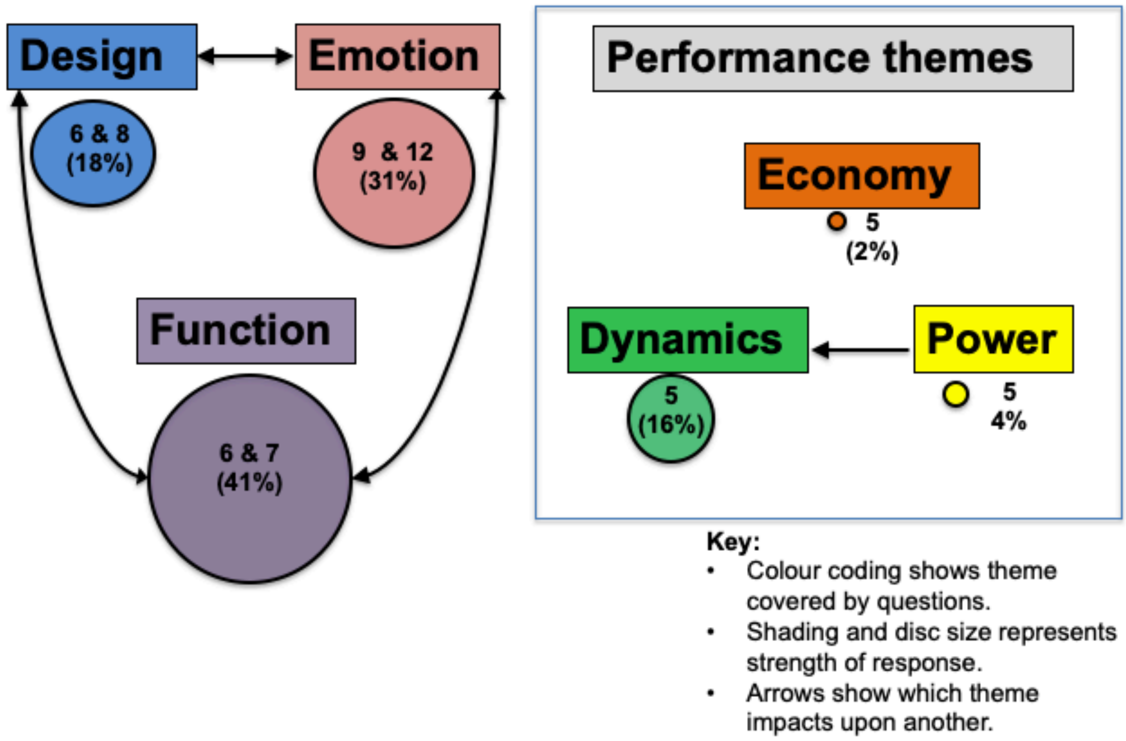


Fig. 6.14. Mental model of survey findings.

Fig. 6.14 shows a combination of the summary and the results from the responses to the questions and use of words from Fig. 6.13. This gives an idea of the importance of Design and Emotion to the customer. The size of the discs represents the most used words in customer descriptions and the numbers show the questions in the survey to which they relate. Question 6, being the one where people logged technical details of their car naturally covered the more functional issues of power, dynamics and economy. However, function itself as a category attracted a large number of responses at 41%, the most of all. Clearly function is a very important issue where PQ is concerned. The arrows show which question affects which, in some cases there is a reciprocal effect, as between design and function; a well-designed control will feel as if it functions satisfactorily. Reciprocally, a control which functions in an intuitive and clear manner may well feel well-designed. However, power will affect dynamics; a large powerful engine my cause over-steer where less power will not. Economy stands on its own as a performance requirement.

Once completed, the thesis was assessed by the originator of the research and the efficacy of this approach (in his view) will be presented as a summary of chapters 4, 5 and 6 in the Discussion chapter 7.

6.7 Conclusions

The results of this survey show that Emotion is a central component of PQ and age represents a significant factor in terms of how this is realised (as in Fig. 6.11). This shows the pre-family or early family times for people and the post family times, whereas the age ranges between these two are more focused on practicalities.

The aim of the current survey was to see if the all-important end user or customer was driven by the two issues of Design and Emotion. The principal conclusion from this chapter is that clearly these two issues (the first an attribute, the other an effect on a customer) form a large part of the assessment, definition and measure of PQ. This therefore answers the research question posed.

The analysis also shows how important the subject of function is to customers – a vehicle that looks good and has a positive emotional effect is no use if it has for example, only two seats and the user has a family. The evidence seen in this survey also suggests that there is occasionally small differences in the attitudes of experts and novices to PQ. The experts were defined as people who are in the automotive industry and novices those who had no automotive or engineering knowledge or qualifications. This was not expected, but nonetheless a useful part of the exercise.

Automotive advertising slogans were considered in a section 2.2.5 and below is one tied directly to emotion. As this thesis is presented for submission, the latest TV advertisement for Mazda cars sums up PQ in a strap-line, succinctly paraphrasing much of the current research on PQ:

"We don't just engineer to specs. We engineer to a feeling".

(Mazda UK 2019)

Chapter 7 - Discussion and Conclusions

7.1 Background

The ‘golden thread’ for this thesis has been the investigation of PQ and how it can be articulated, conceptualised, assessed and measured (see chapter 3.1.1). As discussed in the background to this research (section 1.1), the initial drive was a commercial need at an automotive consultancy to find out more about PQ, its definition and arrive at a better measure for PQ. This allowed for a detailed examination of not only how to assess and measure PQ, but to understand the nature of PQ (Chapter 2).

The thesis research question set out to examine “…if there is a more satisfactory method of assessing or measuring PQ than the current available means, which usually involve giving a numeric rating, to propose a more qualitative method for the assessment of PQ in the Automotive Industry.” (see section 1.5). This was originally set by a need in the engineering design consultancy for more information on what PQ comprised and how to assess and measure it in relation to vehicles; thus, a commercial requirement for greater understanding of this construct existed and could be addressed by the research herein described. Attempts by industry to pursue a deeper understanding of PQ has traditionally not produced many answers in the public domain, at least. This is somewhat incongruous as industry is thoroughly conversant with measuring PQ on vehicles, but usually rating them numerically. However, this somewhat cold, quantitative metrology system was felt lacking a qualitative dimension. The research within this thesis addressed these issues and provides a more tangible understanding of what constitutes PQ in order to facilitate a better means to quantify it.

Achievement of the research aims were assessed early in 2019 by the Quality Manager at the original company. The extent of the meta-data literature review and critique, the efforts of others to investigate PQ and the three surveys conducted convinced this person that a thorough piece of research had been carried out.

7.2 Thesis Validation

At the completion of the thesis, the Quality Manager and the Quality Auditor were interviewed and were each given a Declaration to sign as to their opinion on the work. They were given three options to score the work.
These are:

1. Original questions completely answered.
2. Research has gone some way to answering the original question.
3. Project has not succeeded in responding to the original need.

However, their views after a presentation of the thesis and a detailed discussion follow, with both scoring the research as a 2 from the above choices.

<u>Quality Manager</u>
"Ian has addressed two of the key elements, namely search and focus group data collection (limited in scope). I was expecting Ian to take the feedback from both elements and provide a recommendation to how we should be setting the PQ targets and how they are achieved during the vehicle development process. Without this, I cannot fully see how the thesis advances the subject significantly , whilst still fully appreciating the time and work that has clearly gone into the project to date."

<u>Quality Auditor</u>
"Not delivering a definitive process for achieving a satisfactory vehicle PQ any different to the process which existed previously."

Their views have to be accepted and the possibility was discussed that there could even be no better method of assessing PQ than the one we already know.

(Sadly, the Company for whom we had all worked effectively closed its UK Engineering operation some months before the validations).

7.2.1 Response to Validation

However, these are comments from Industry perspective - both looking for an answer that can be used today in their work setting. Part of the research journey was about defining the problem space and not delivering a ready to use out of the box method for Industry to collate a PQ score. Both comments fit well with this expectation and continues the call from industry to develop such metrics.

This PhD was a significant step in that direction - so both comments serve to endorse what has been achieved in terms of the journey - but both express the need for a destination that delivers exactly what is needed at the end - a deliverable metric of PQ that can be applied across the lifecycle of vehicle production.

Thus a score of 2 is not surprising and reflects their frustration in the expectation of what is required by Industry. This validates the Further Research section following later which suggests that there is still more investigation to be carried out on PQ.

It was vital to see if there was a real alternative to the purely numeric way that PQ was normally presented in the commercial measures with simplistic 1 to 10 scoring regimes. This has been achieved through the mental models.

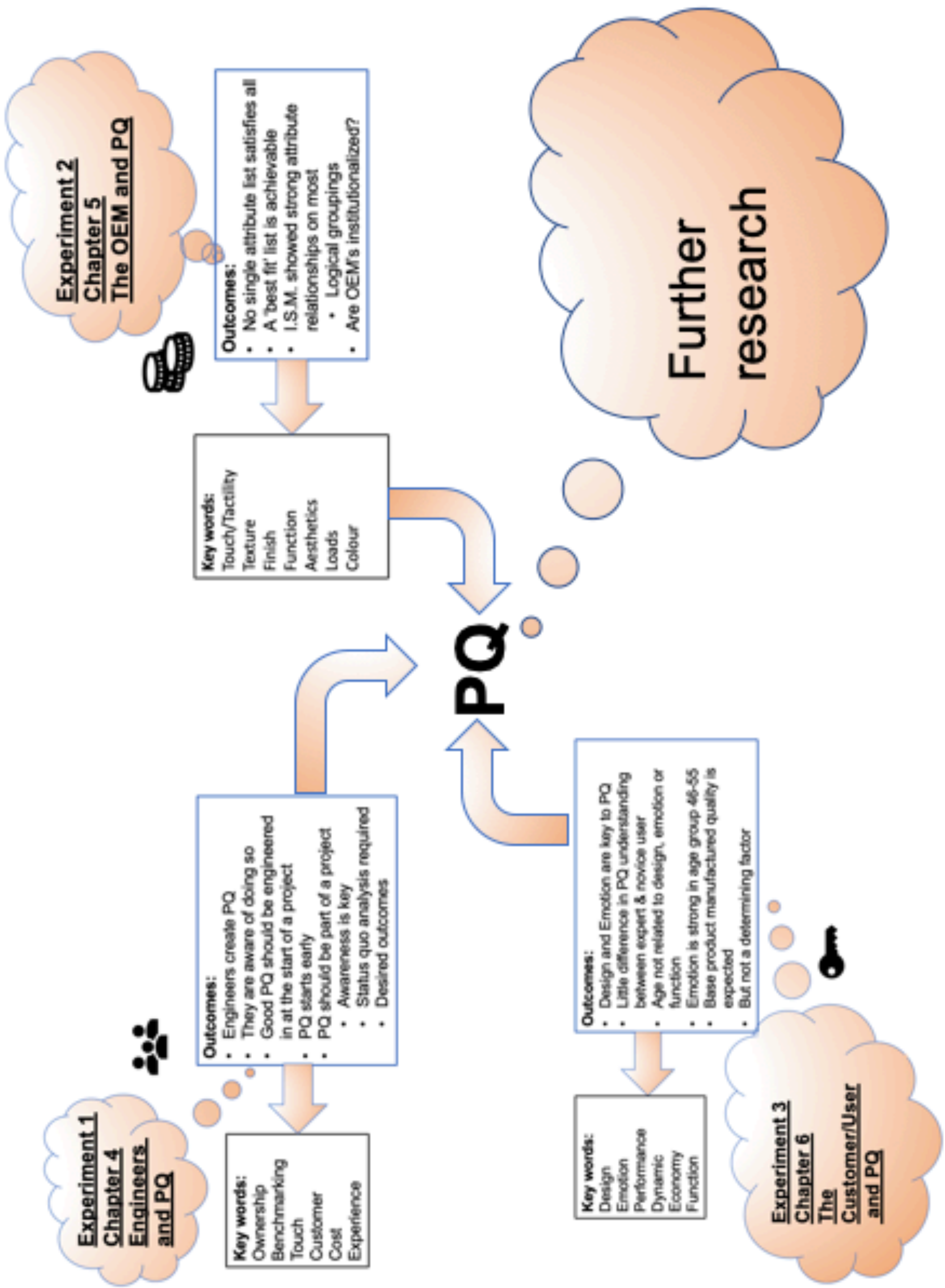
In terms of the alternative to numerical scores, the Quality Manager was attracted to the use of mental models to represent the way people think and conceive of concepts such as PQ. Mental models were introduced in Chapter 1.3.2 and have been used here in a first for published PQ research. The models represent the visualisation of words in terms of frequency that arose from the three experiments. Each Experiment presented its own visualisation of a mental model, summarising the chapter outcomes and key words found during the surveys within the chapters. Fig. 7.1 following shows the merging of these three studies. Fig. 7.3 will bring the key words together in a set of themes as the mental models already shown in the individual survey chapters.

The scans of the Validation Declarations are in Appendix A7.1 from the Quality Manager and Company Auditor.

Fig. 7.1. Composite summary of key words and outcomes from the three surveys

Chapter1 set the background and 2 presented the different aspects to PQ which have been covered in the research so far.

Looking back at the sections in these Chapters, such as 2.6 for the relationship of



sales to PQ, 2.2 for the product issues and 2.1 for the customer issues and some interesting groupings can be drawn, as shown following in Fig. 7.2.

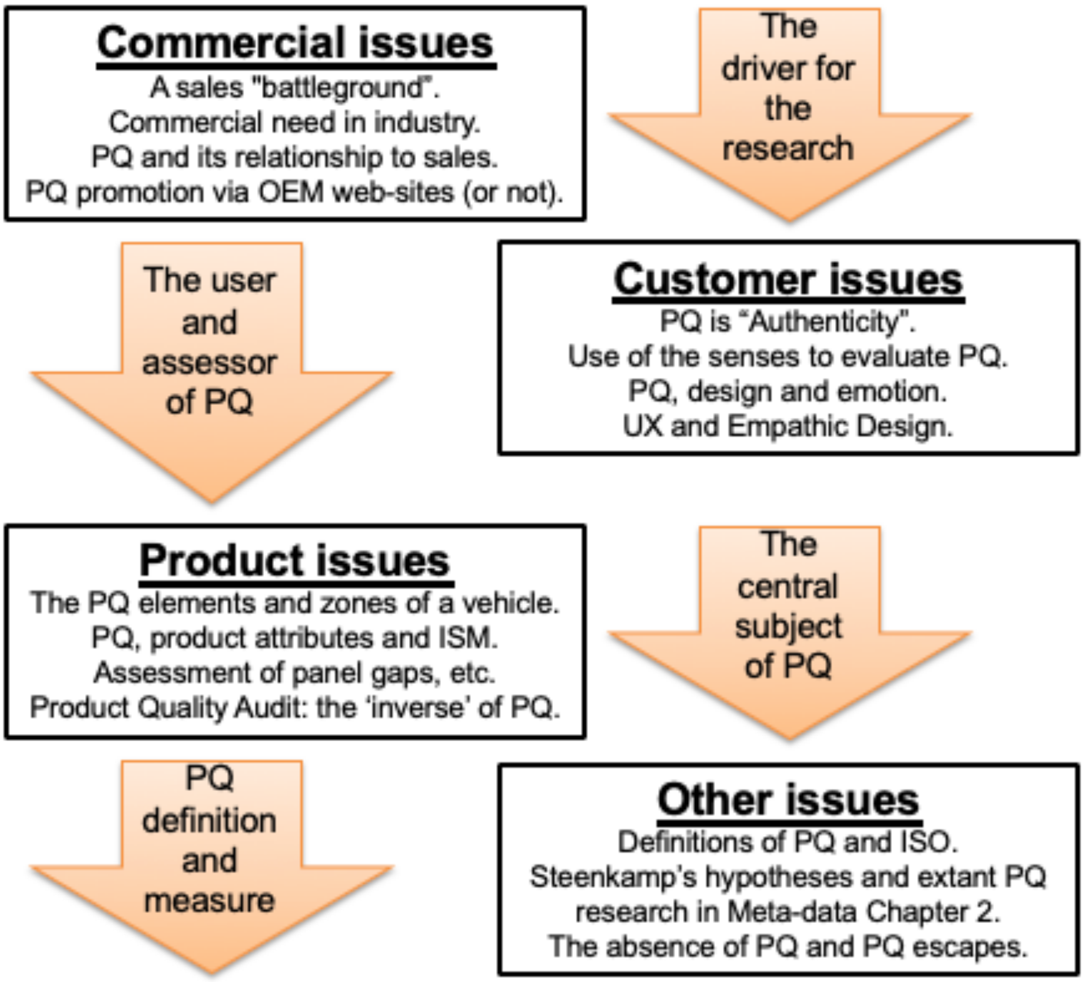


Fig. 7.2 The grouped aspects of PQ, as discussed in the Introduction chapter

Fig. 7.2 shows a grouping of the subjects introduced at the beginning of this thesis. This shows how the thesis has logically covered the issues it set out to do. The commercial imperative for this research back in 2013 has shown itself to be a core issue and was further discussed in each of the experimental survey chapters. The product, be it car, coach, truck or motorcycle was always going to be at the centre of this work as the principal subject, with many sub-issues from the zones of PQ in 2.2, to very detailed panel gap measurements, in 2.2.3.

The customer, central to the assessment of PQ is a constant reference point through the writing and has many ways through the many human senses of creating their own understanding of PQ, which the research has attempted to articulate as visualised representations of possible mental models. All these sets of issues have been discussed and evaluated to serve the aims of the research, which was to come to a better understanding of PQ and create an improved measure, whilst presenting PQ as the series of these mental models. The customer was the central focus of the third study in Chapter 6.

The analysis of PQ was tackled by conducting three surveys of the spread of PQ across the life of a product, from the perspective of:

1. How Engineers create PQ in the first instance.
2. How OEMs manage PQ and act as custodians, developers and promoters.
3. How customers view PQ.

The impact of these surveys on the original Research Questions introduced in Chapter 2 has been to suggest that design and emotion play a significant part in PQ measurement and that aesthetics at each of the three survey points was a strong component. Aesthetics were introduced in the first chapter section 2.1.4, for example, looking at the role of the senses. Further discussion on aesthetics came later in section 2.2 on automotive PQ and was revisited many times such as section 2.2.2 where the aesthetics of panel gaps was discussed and Figs.3.2 and 3.3 looking at panel and gap quality in the survey on Engineers. Again, in the survey on the OEM in chapter 5, aesthetics or design were crucial issues for the manufacturer and in the assessment of attributes by the OEM PQ management team, many of these were aesthetic points, such as wheels and tyres.

Tactility emerged at Level I of the ISM analysis in section 5.2.3, with panel finish, colour, surfacing and transitions, at Level II, etc. These were rated by the OEM PQ team and the digraph created as shown in Fig. 5.10.

Function also came out of each survey as a vital common component – see the summary in Fig. 6.1. Its prominence was less marked in the survey on Engineers, but very evident on the OEM and Customer ones. Fig. 6.3 shows the level of feeling for function.

It was expected that value for money would be a shared thread for each survey, but this was not borne out by the results. It is not clear why this is so and may be an avenue for further research.

The surveys took real data from those involved at each stage of PQ and presented it in various ways that seemed pertinent to the three groups. It was expected that much of the data generated would be qualitative as the subject matter dictated such a direction and that descriptive language would be a huge component of the end result.

The summary in Fig. 7.1 is a composite of the summaries for each survey or experiment described in Chapters 3, 4 and 5, leaving an open question for further research. It shows that key words run across the elements, such as function, touch, design, and emotion. These add a more qualitative aspect to measuring PQ.

The summary for Chapter 3 on Engineers creating PQ (bottom left of Fig. 7.1) shows key words of ownership, benchmarking, touch, the customer, cost and experience. Some of these are echoed later in the research, such as touch in the attributes listing in Chapter 4. Table 1 following lists the key words for each chapter and attempts some categorisation by themes.

Table 7.1. Key words and themes from summaries of key words in Fig. 7.1, shown in survey chapters as numbers 3 to 6.

Key words organised thematically (with chapter numbers).			
Subjective/ emotive	**Objective/ measurable**	**Sense**	**Financial**
Ownership (Chapter 4)	Function (Chapters 5&6)	Touch/tactility (Chapters 4&5)	Benchmarking (Chapter 4)
Experience 4	Performance 6	Texture 5	Cost 4
Customer 4	Dynamics 6	Finish 5	Economy 6
Design 6	Control loads 5		
Aesthetics 5			
Emotion 6			
Colour 5			

From Table7.1 above, it is interesting to note that there are no key words common to all three surveys and just the following common to two surveys:

- Function (Chapters 5&6)
- Touch/tactility (Chapters 4&5)

It could be argued that the three items grouped under the Sense column could be covered under the subjective issues of aesthetics. Cost or more specifically, value for money, was expected to be a common theme and was mentioned in the Engineers survey in chapter 4 and in the customer survey in chapter 6.

Does this mean, then that just these two – function and touch are the principal issues in PQ?

Logic would dictate no, as surely the first, most immediate assessment of any product is conducted with the eyes and therefore design, including concepts such as aesthetics and colour would be the most immediate factors here.

Looking at the mental models produced by the three surveys, the composite diagram below in Fig. 7.3 shows all the three survey mental models

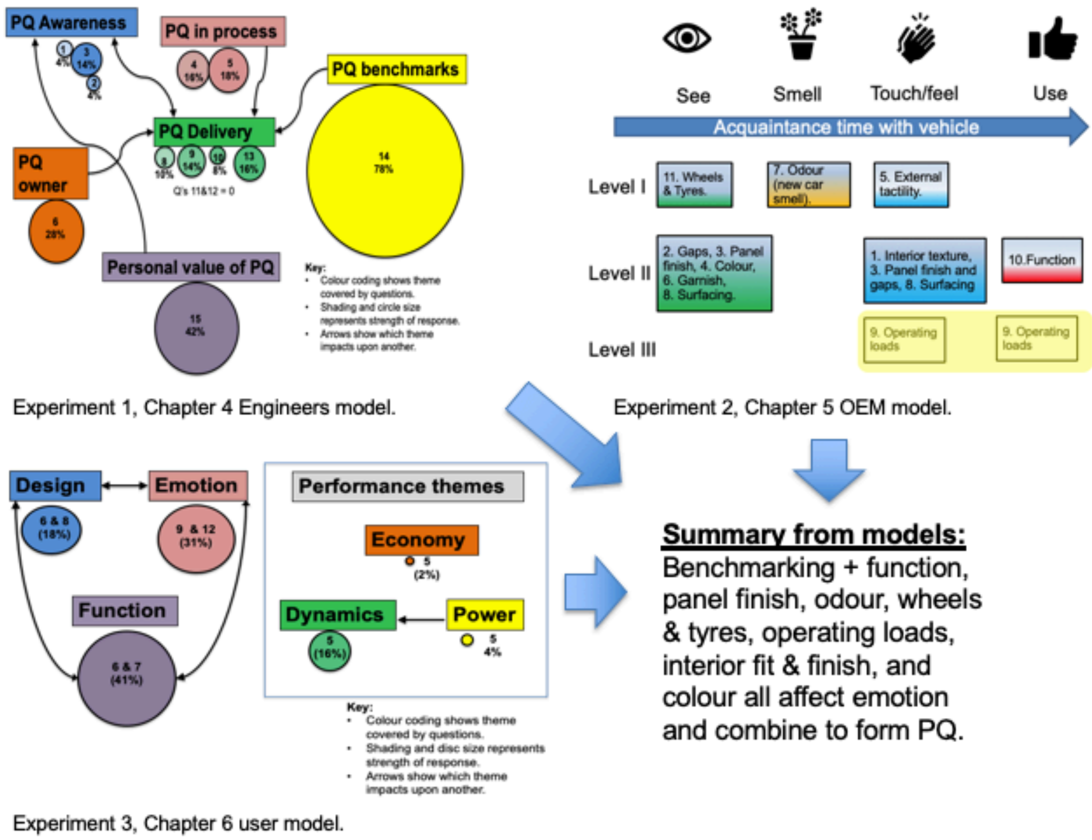


Fig. 7.3 Composite summary of mental models from the three surveys.

Pulling the principal findings from these three experimental surveys shows that certain actions or aspects of PQ are worth concentrating upon.

From survey 1 in Chapter 4, the view of the Engineers who create PQ, is that they are looking for benchmarks to assist them in 'designing in' PQ. Their personal view of PQ also colours their work, with over a quarter wanting a PQ owner to be apparent and lead the process. From the second survey on the OEM, of the four principal senses used to assess PQ, operating loads came out as a Level III driver from the ISM process, with colour, aesthetics and interior fit, finish at Level II and wheels & tyres, interior odour and panel fit at Level I. Survey 3 in Chapter 6 showed the PQ aspects for customers are design and emotion, plus function. All other themes within the performance grouping have low scores.

7.3 Kano theory across this research

Kano theory was introduced in Chapter 1.6 as a thread linking this whole thesis on the assessment of PQ. It has been referred to all through the research; in the Meta-data chapter as an important piece of the background literature and in each of the three studies or experiments on the creation, management and consumption of PQ. It is a constant link across this work.

Although a fairly simple graphical concept as shown in Fig. 1.3, the fact that the model changes with time as those factors which were 'delighters' at one point of a product's life eventually morph into expected factors, shows how complex the model can become. This is true of PQ.

Chapter 3 considered over 330 pieces of literature which contributed towards greater understanding of PQ. Kano's model was already known to this researcher and suitable references were added to the store of knowledge (McCabe 2019, Verduyn 2014, Holst 2012, Matzler and Hinterhuber 1998).

Throughout Chapter 4, the study on Engineers and their creation of PQ, Kano theory was strongly relevant. Engineers were aware of the changing nature of attributes or features on which they were working being 'new' one model year and the requiring refreshing or otherwise updating continually.

In Chapter 5 on the manufacturer's PQ attributes, we looked at attributes that make up PQ and if it were possible to create one single agreed list of these and concluded that it is not. Part of the reason is shown in Kano, again in that time changes attributes from delighters to basic.

Looking at the Customer in Chapter 6, the research question set out to examine the link between PQ, Design and Emotion. The meta-data search had shown there to be one and the link modelled in Fig. 6.1.

The mental model showed a strong link in Fig. 6.14, with the final line of Chapter 6 quoting Mazda's view: "We don't just engineer to specs. We engineer to a feeling"(Mazda UK 2019). Like many Japanese car companies, Mazda embraces many of the quality tools such as Kano theory and this quote acknowledges again the need for "specs" (specifications) as a basic Kano issue, but also that PQ, with its emotional link proven, can change issues over time.

7.4 Case study opportunity

It was clear that changing employers (see Section 1.1) from a value-for-money manufacturer to a premium one, presented an opportunity to use case study methodology. This opportunity was deliberately not taken, as with such a wide subject as PQ, a clear narrow focus on what was believed to be important to the thesis and unique to it had to be maintained. The multi-disciplinary nature of this research, looking at an Engineer's view of PQ and then psychology through the mental models would have had a rich seam of two completely different corporate cultural psyches to compare and contrast, it is true.

Previous research examining PQ, as covered in Chapter 3 Meta-data, seldom used case-study methodology. One paper that did accomplished very much the same result in a case study as this thesis achieved by conducting a survey on employees(Stylidis 2015). The limited others who did were examined, such as Duraiswamy *et al*. (2018),who confined their research on PQ merely in terms of split-lines, a subject already covered in this work (see section 2.3).Therefore, the decision taken in this thesis was not to use case study methodology and to use a survey approach.

Some possible reasons for other researchers not using a case-study could be:

- Access to OEMs to study PQ is closely guarded.
- Few researchers gain such entry.
- Many of those who do are employees, who have to be seen to act in their employer's best interests.

- In the paper referenced above, three of the four authors were JLR employees and the PQ issues were confined to split lines, aspects that can be measured by any visitor to a dealer.
- Any access given (such as to this researcher) is controlled and permission to use resultant data is difficult to obtain.

There were many other avenues which would have been interesting to pursue, such as a planned chapter on PQ in other industries, but the researcher and Supervisory team made the decision to not investigate certain aspects, such as Brand, for this would have made an already wide-ranging piece of research just too weighty. Time also precluded the inclusion of certain subjects and these may be considered by anyone wishing to add to this examination of PQ.

7.5 Implications of this research

So, what does all this mean and how does this inform Industry? The implications for this research have been fed back to the original requester, the Quality Manager at the engineering consultancy mentioned in Chapter 1. In many ways, what has been discovered in each survey vindicated what that consultancy has been applying vis-á-vis PQ audits for over a decade. What was revealed throughout the research was that PQ is an evolving and currently relevant area of study, with some active on-going research. The implications could be that with a trained PQ professional, the need for a full day vehicle assessment may be reduced considerably by focusing on the aspects described by the key words in Table 7.1 and the summaries in Fig. 7.1, followed by the mental models in Fig. 7.3. These would appear from the surveys' evidence to be the most significant components of automotive PQ.

As for presenting a new measure for PQ, one of the aims of this research, it is feasible that just the common key words found through the surveys could be used (design/aesthetics, emotion, function and touch/tactility) to describe the PQ of a vehicle, almost as a short-hand.

Rather than organise and facilitate a whole day on a PQ workshop, attempting to coerce participants away from their normal duties to participate, the exercise could be conducted by a trained PQ Engineer using just these key words. The Engineer could focus on these words and rate the vehicle on these alone.

To go with the words, some form of fuzzy language descriptors could be applied, as in more/less, or better/worse than expected. Fuzzy language is mentioned here as a useful phonological to describe PQ, which as we have seen is so different from subject to subject (as shown in chapter 6 survey responses, such as table 6.2). It is more normal or expected in an engineering environment to err towards very crisp definitions of attributes, using metrological scales such as dimensions. Fuzzy comes from the opposite extreme and such language would make a useful next step in PQ research, discussed further in section 7.4.

7.6 Contribution to knowledge

In terms of a contribution to the knowledge on PQ, this thesis has taken a much wider view of PQ than other research that has been accessed, reviewed and critiqued. The only thesis on PQ found in the meta data review concentrated upon panel quality (Wagersten 2013: 3). Yet another important reference work was a consideration of tactility alone regarding interior trim, so again an important piece of detailed work, but still a narrow focus (van Laack 2014).

Regular mention has been made in this thesis of the excellent PQ work conducted at Chalmers University in Gothenburg, in conjunction with Volvo, yet again these are often with a specific focus, such as those papers shown in Table 3.1 (Wagerston *et al.* 2009, 2011 and 2013). Other useful papers such as Kouprie, M. and Visser, F. whose research entitled “A Framework for Empathy in Design: Stepping into and Out of the User's Life”, just looked at the aesthetics issues (2009).

Some of the issues covered in this work have not been given adequate coverage to date, at least via material accessible in the public domain. Of these include the role of the many human senses and the use of mental models to ascribe shape to views of PQ (Johnson-Laird 2005: 187).

Much of the extant work takes a very narrow or specialized view of PQ, such as panel gaps and panel form. This is only a small component of PQ.
This thesis also takes the view of PQ as a journey from its creation by the Engineers and developed by the OEM, to consumption by the User and in this respect is a unique piece of work. As the research has been conducted from within the confines of an automotive industry employment perspective, this is also unusual, as such views are often kept within the industry itself. This gives a distinct relevancy and public validity to the contribution.

7.7 Conclusions

PQ is as presented here, a multi-facetted, complex concept, much more than simple measurables like panel gaps or tactility of surfaces: these are merely two facets. It certainly involves these, but is much, much more.

Humans assess PQ almost in an instant, using a combination of several senses and therefore humans should be at the core of any PQ study. This is why the journey of PQ described herein, places the user/customer as consumer of PQ and uses the third survey in chapter 6 to capture and generate the VOC (Voice of the Customer). The creation of PQ by the Engineers was given shape in the first survey described in chapter 4 and was then developed and supposedly promoted by the OEM as shown in survey 2, chapter 5. However, the evidence shown therein concludes that the OEMS (with the exception of some such as Lexus and Peugeot) do little to disseminate or foster PQ, other than a few advertising slogans illustrated in Chapter 2.2.5.
Should it not be that the OEM stands at the centre of PQ, driving its creation by the Company Engineers, managing and promoting PQ and ensuring the user/customer understands and appreciates PQ, who then use this knowledge represented in the mental models from each of Chapters 4 to 6, to select or purchase a vehicle based on its PQ?

This thesis has shown that PQ is a vital element in the Purchasing or selection decision and therefore PQ has strong commercial value. This may change along the lines described in the preceding Discussion as the vehicle market develops and changes. The assessment of this value is time-consuming for an OEM to understand and measure and one outcome of this thesis is the suggestion of a foreshortening of such a process, by concentrating on the elements of PQ which really matter according to this research.

So, a new assessment for PQ has been described in the summaries and mental models shown in each chapter and the thesis Discussion which brought them all together. The weightings of PQ aspects in the mental models shows where the real value and accents of PQ exist.

What has been created in the course of this work is a unique multi-disciplinary approach to conceptualising, measuring and expressing PQ. The combination of a straight engineering view mated with a psychological approach is thought to be a first in the study of PQ.

7.8 Further research and the future of PQ

Although a comprehensive view of all aspects of PQ has been taken here, there still remain many avenues which were planned to be explored, such as the information generated by customer clinics of new vehicles. One such clinic was observed, and it was clear that a great deal of information could be gleaned from watching such an activity (see Chapter 2.8).

In such clinics, which are conducted by many manufacturers not just automotive, a specialist agency is used to contact consumers and ask them to attend the clinic. This ensures that target customers are recruited who may be in the market for a forthcoming product. In the case in question, a large room was provided, in which were six full-size detailed models of proposed vehicles.

The observer's role is to listen and watch remotely via audio/visual links as the skilled facilitators take the attendees through a script and gauge the response to the planned vehicles.

However, time pressure and issues of confidentiality did not allow the results from this event to be investigated and see what customer views of PQ lay therein. This was described in section 2.8.

These may have been similar to those encountered in the customer survey in Chapter 6, but there may have been new aspects. Unless one has the position of an industry 'insider', these events are naturally almost impossible to access, and it is such an alien environment to most that some degree of experience and skill is required to process the immense amount of resulting information.

Another intended direction for the research was to analyse whether the use of fuzzy language was relevant to creating a new measure for PQ. Some work had been conducted in the engineering consultancy where this research began and had shown that changing language from distinct or specific to fuzzy, had produced some worthwhile results in shortening, generating greater efficiencies and understanding in the running of PQ audits. Again, time prevented this avenue from being explored fully.

The future of automotive PQ is inextricably tied with the future of the subject itself. Some writers predict the steady decline in vehicle ownership and moves towards more car-sharing or very short-term hire, such as those trialled in various cities across the globe firstly on two wheels and now on four (Arib & Seba, 2017). What effect will this have on PQ? Less ownership could mean that PQ as a component of the purchasing process (as described in Chapter 2, Fig. 2.14), will become less of a driver in the selection of a particular vehicle.

Conversely, as vehicles become more Automated, the interior aspects of PQ could become more important, as the user will have more time to consider their environment as less time is devoted to looking through the windscreen. PQ is and remains a commercially important subject for further research as the market develops and changes.

Throughout all the three surveys presented herein, the search for an improved understanding and measure of PQ has been made and each further level of understanding the journey of PQ from creation to consumption returns back to the one word uttered by an OEM PQ Manager (Harris, 2016) and remains true to the end of this piece of work –

AUTHENTICITY.

Chapter 8 - Author's work and publications in support of this thesis.

The following were created in pursuit of researching the thesis.

Date	**Activity, paper, article or event**
October 11th 2013	Enrolment on PhD course.
February 13th 2014	Enrolled on employer's extra-curricular DFSS (Design for 6 Sigma) Quality course*(Note 1).*
March 14th 2014	Visit to Triumph Motorcycles UK to discuss PQ.
April 2nd 2014	Design and Quality lecture given to Industrial Design Dept. at Coventry University.
May 30th 2014	Visited Iain Mitchell, MD of Iain James Furniture, Long Eaton to discuss non-automotive PQ. *(Note 2).*
June 22nd 2014	Visited SAIC, Shanghai China to collect data for DFSS PQ project report for possible inclusion in PhD.*(Note 3).*
August 7th 2014	Accepted as MCQI - Member of the CQI (Chartered Quality Institute) and accorded title CQP (Chartered Quality Professional). Therefore, gained access to their database.
December 11th 21014	Arranged meeting for fellow PhD student to present work on PQ at Author's place of work to Engineers.
January 6th 2015	Article accepted by CQI for inclusion in their Journal "Quality World" – see Appendix A1.2, published February.
May 6th 2015	Faculty Research Symposium – Poster presentation.
January 5th 2016	Successful meeting with JLR Board Director for Quality to discuss continuation of PhD project in new employer.
February 16th 2016	Faculty Research Symposium – Poster presentation.
February 21st 2016	Submitted paper to UKACC on PQ and Control.*(Note 4).*
April 19th 2016	Presented paper at Doctoral Consortium within the

	Ergonomics and Human Factors Conference, Daventry.
May 5th2016	Presented PhD to date at Coventry University Research Exchange.
September 30th 2016	Presented PQ paper to Design and Emotion Society at D&E 2016 in Amsterdam.
March 29th 2017	Faculty Research Symposium – Poster presentation.
August 10th 2017	Submitted new PQ paper to IJVD (international Journal of Vehicle Design).*(Note 5).*
January 15th 2018	Presented PQ in "3-minute Thesis" inter-University competition.*(Note 6).*
January 30th 2019	Presented thesis at Engineering Consultancy where original Research Question was set.

Note number	**Supporting information**
1	This was at least 6 hours extra work per week and a PQ-themed project was accepted by the Employer, but following months of work, this was rejected, as was a 'replacement' product quality project. Shortly afterwards, the employee was made redundant.
2	This visit to a non-automotive manufacturer was intended to support a planned chapter in the thesis on "PQ in other industries". This plan was later changed by the Supervisory team. This is still considered to be a future investigative avenue for PQ research.
3	This visit was to gather data for the second DFSS project mentioned in *Note 1* but was also used to research PQ in another market.
4	Paper encouraged by original (Control Engineering) DoS but rejected.
5	Paper rejected.
6	Did not reach University final team.

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Appendices

Chapter 1

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Appendix A1.1. E&HF Conference, Staverton Estate, Daventry 17th April 2016

Abstract - General Background to the control of Perceived Quality

Perceived quality is a broad church. By definition it's based upon personal perception. Therefore, there are as many definitions as there are perceivers, or quality gurus, as above.
Good PQ can turn a prospective customer into a passionate one, or if the quality is not what was expected, turn them away.
Kataoka (2004: 1) described it as "a sense of quality that users actually feel when they see, touch and use a product", while Petiot (2009) defined it as multidimensional in nature. Fernandes & Alves (2012: 28) explains that it "can be understood as the relation between perceptions and expectative, in other words, the difference between what the customer really receive (*sic*) and what he waited to receive".

Perceived quality could be viewed as the new battle-ground to win customers in the cut-throat automotive world. It is vital to discover for any automotive company to understand what contributes to PQ and what degrades it. In order to produce desirable cars, it is important to discover how PQ can be controlled.
Perceived quality runs across the entire creation process, starting in the design function, running right through to the receipt of the product or service by the customer.

This current research will consider what has been postulated on the subject so far. This will be assessed within the confines of the automotive industry, as it struggles with the seemingly polar opposites of cost-reduction and Perceived Quality.
Perceived quality is a continuous process across both product and service sectors. It never stops. An enterprise that does not measure, articulate or otherwise attend to perceived quality may lose custom.

Although some research has been carried out in the measurement of PQ, but very little appears to have been published on the subject of controlling PQ within the automotive sector and the effect on the customer. This is where the innovative, unique point of this research is heading.

Future work will look at objective measurement (heart rate monitoring, eye-tracking, etc.)
A mental model of customer preferences and how subjective PQ can be translated this way is urgently sought. There is much to be learned and developed in this study.

Appendix 1.2 Scan of Journal article in Quality World (2015)

Some materials have been removed from this thesis due to Third Party Copyright. Pages where material has been removed are clearly marked in the electronic version. The unabridged version of the thesis can be viewed at the Lanchester Library, Coventry University.

Chapter 2 Appendices

Appendix A2.1 The many Human senses used in PQ assessment

In order to expand upon the human senses, listed below are details of how each one of the principal senses is related to PQ.

<u>Vision.</u>

Covering sight would be, is and has been, the work of several theses, so a short introduction to the role of sight and its relationship to PQ is all that is intended here.

Sight and its measure of aesthetic appeal is clearly the principal and often first draw towards any product. We see and assess quite quickly. The human eye has the equivalent of 576 megapixels, can discern a wide spectrum of colours and is linked to a storage facility for millions of pictures. It is not unknown for us to look at what someone else is eating in a restaurant and without tasting it, order the same dish, based principally on the visual appeal. An accompanying alluring smell will often confirm the choice.

In PQ, vision and aesthetic appeal dominate our assessment of product. Customers of luxury vehicles will pay many thousands of pounds, dollars euros, etc. for a bespoke different coloured car or combination of interior materials to set themselves apart and improve their car's PQ. Many OEM's have their own bespoke after-factory or other facilities incorporated into the main plant to produce tailor-made product. Some have their vehicles taken by separate companies and 'enhanced' to meet personal taste. It used to be the norm for one firm to produce a chassis and yet another to build a body thereupon, however today the various crash and other regulations mean that this is still the case in the commercial vehicle world, but cars and motorcycles are generally fully built.

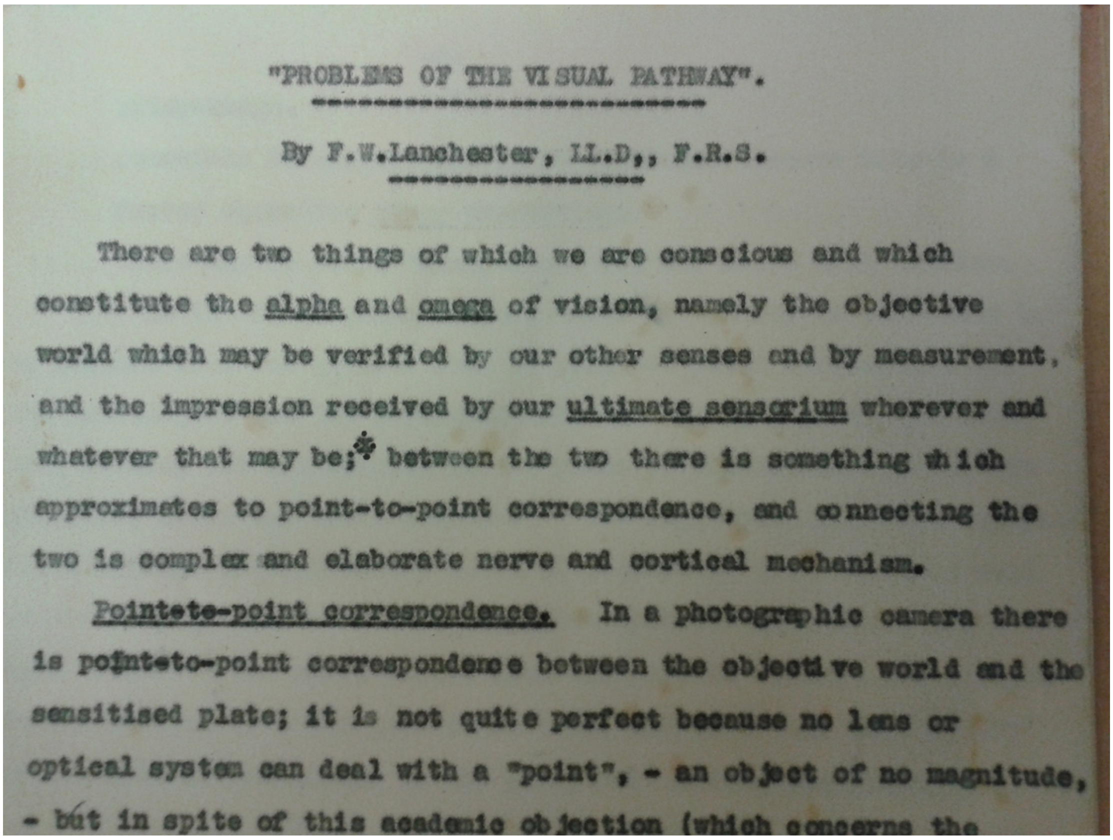
Sometimes, they are then later customised by companies such as Karmann, Alpina, Abarth, Overfinch, Irmscher and thousands of other, smaller concerns in almost any country on the planet. Aesthetics is big business.

1. Sight is such a well-used sense that about half of the brain's capacity is required.
2. Eye cells are composed of two different shapes; rods and cones.
3. Shapes are communicated by the rods, and cones allow you to see colour.
4. A blink occurs about 12 times every minute, the average blink lasting for about 1/10th of a second.
5. The most active muscles in a human are those controlling the eyes (VSP 2018).

Bearing in mind the facts above, aesthetics will affect PQ judgement above all other senses. This is borne out in the surveys conducted for this research. A vehicle's shape and colour is usually the first assessment made. The eye will discern panel gaps and profiles, areas of dark and shade, form and fit, geometry that is pleasing or otherwise, all within a few seconds. Sight infers other characteristics of a product; something may *look* heavy, (but not necessarily be so), a seat may look comfortable (Erol et al. 2014). Watkinson asks his readers "What qualities of the brand or product must be conveyed through its appearance?" Clearly, sight is a vital sense for PQ. Dr. Frederick W. Lanchester L.L.D., F.R.S., wrote extensively on ophthalmology.

He had this to say about sight which is quite relevant to PQ:

> *"There are two things of which we are conscious, and which constitute the <u>alpha</u> and <u>omega</u> of vision, namely the objective world which may be verified by our other senses and by measurement, and the impression received by our <u>ultimate</u> <u>sensorium</u> wherever and whatever that may be; between the two there is something which approximates to point-to-point correspondence, and connecting the two is complex and elaborate nerve and cortical mechanism."*


"PROBLEMS OF THE VISUAL PATHWAY".

By F.W.Lanchester, LL.D., F.R.S.

There are two things of which we are conscious and which constitute the alpha and omega of vision, namely the objective world which may be verified by our other senses and by measurement, and the impression received by our ultimate sensorium wherever and whatever that may be;* between the two there is something which approximates to point-to-point correspondence, and connecting the two is complex and elaborate nerve and cortical mechanism.

Pointeto-point correspondence. In a photographic camera there is pointeto-point correspondence between the objective world and the sensitised plate; it is not quite perfect because no lens or optical system can deal with a "point", - an object of no magnitude, - but in spite of this academic objection (which concerns the

Fig. A2.1. An excerpt from Dr. F W Lanchester's own publication "Problems of the Visual Pathway", held in the Lanchester Archive, Coventry University (Lanchester 1934).

Lanchester was not writing about PQ, but an Engineer and polymath of his standing will have been aware of many of the principles discussed here. Certainly, panel shut-lines, gaps and profiles of the cars that bore his name will have come under his scrutiny.

<u>Touch.</u>

In PQ terms, this sense only has an input once the object is available to touch. It requires effort on behalf of the appraiser to engage with the vehicle or part thereof that is being assessed. From just one touch a whole stream of information is available; tactility gives us ideas of shape, texture, surface roughness, weight, soft or hardness, comfort, dimensional data and even temperature. The keyboard of this Apple MacBook is a mix of smooth, warm plastic illuminated keys and a hard, cold, sharply defined case.

There are many PQ messages being transmitted to the user's brain whilst typing – it is good to type on yet leaning the wrist on the case causes it to feel cold. 'This is a serious bit of industrial art', perhaps, 'It is a solid, metallic-looking and feeling case, which will last', could be another.

According to Kukova again, this sense does not operate at the first stage of car ownership, the research stage, unless the research is done in the dealership, which is stage two anyway (Kukova 2016). In terms of the three stages of ownership, touch really only occurs at two and three. Touch does convey a certain amount of what Watkinson refers to as 'psychological ownership" – once an object is touched, then a potential customer is a stage nearer to purchase, the golden thread in this thesis. Visual and haptic perception are strong influences on the purchase decision and are central tenets in an important piece of research by Alexander Walter van Laack, whose scientific research leading to his dissertation was entitled "Measurement of Sensory and Cultural Influences on Haptic Quality Perception of Vehicle Interiors", more of which will be discussed later (van Laack 2014). Van Laack succeeded in conducting several research clinics, looking at the power of touch and finding ways of measuring what the human fingers can sense. He matched subjective and objective data and came up with suitable transfer functions, which made his research applicable in the laboratory and in the real world.

<u>Scent.</u>

Possibly the most evocative scent, judging by the amount of money lavished upon fragrances for both sexes.

Long-forgotten memories of places and people are conjured up by scent. Yet despite all this, it is perhaps the least understood of all the senses. New car smell has already been discussed and is not unanimously appreciated. Watkinson argues that "there are few universally appealing smells; we also typically become acclimatised to a scent within 15 minutes or so, at which point it loses its effect, unless we leave the vicinity and return again". (Herz, R.S. 2010, cited in Watkinson 2013). With over 1,000 distinct olfactory receptors able to identify or respond to different odorous molecules, a human is very attuned to scent.

For example, Chinese customers react strongly to any odour in a new car: what in the West would be called 'new car smell' (E&T Editorial Staff 2017).

This is as a result of the oils, releasing agents and other VOC's – volatile organic compounds – present in plastic mouldings being activated by solar radiation. Chinese customers do not want any odour of any such kind (Chen 2017). Some manufacturers have attempted to counteract this by masking the new car smell, but this market is clear in that it wants no smell at all. It is possible to see new cars in China sat with all apertures open, just venting, before the customer will drive them regularly. Many luxury car manufacturers are known to be working on odourless interiors.

<u>Hearing.</u>

This is a key PQ sense, which like touch, can really only work in stage two and three of Kukova's three stages of ownership. Noise is again a very subjective issue; what is music to one may be an offensive din to another. The same applies to PQ and noise. To most Western car fans, a sports car should have some sort of induction and exhaust noise. For instance, a V8 engine would be expected to have a characteristic 'burble' sound, not loud, but audible to show that there is a large V8 under the bonnet and not a small 4-cylinder.

However, other cultures, such as China, believe that a car should be very quiet and even if it is a sports car, the less noise the better.

This is demonstrated by the advertisement below in Fig. 1.2 for an MG6, a car designed and developed by a joint Sino-British team.

In the expected noise for a car bearing the MG octagon, however, the Chinese specification severely restricted the exhaust back-pressure, resulting in a quiet exhaust.

Fig. A2.2. MG Aftermarket JWM exhaust, featured in MGCC Journal Volume 61, Issue 4 April 2017

Engine sounds have been the result of some interesting research, which will be discussed later (Abe et al. 2004, Nosulenko, Parizet and Samoylenko 2013).

Hearing is a sense that is difficult to deny or turn off.

We can close our eyes and not see, but short of noise cancelling headphones, it is difficult not to hear that which is around us.

Some automotive companies have used the absence of noise to convey quality, notably perhaps Rolls Royce, who used a tag-line that suggested the noisiest intrusion into their cars' interiors was the ticking of the dash-mounted clock.

BMW used the balancing of a coin on their engine in 1990's television advertisements to show an absence of vibration and therefore noise.

Quality of sound has often been discussed in automotive circles. The sound made by a vehicle has frequently been the subject of a manufacturer's quest for the 'right' sound for the vehicle in question.

In the defunct MG Rover Group, the two marques (MG and Rover cars) were expected to be separated by style, ride and many other attributes, one of which was sound. The manufacturer believed (and had some evidence to back up this conviction) that traditional Rover customers wanted quiet, serene interiors, with little intrusion from the powertrain or suspension, whereas MG customers wanted to be able to hear their engines work, with some form of induction and exhaust noise to accentuate the sporty feel. Looking through the pages of any car, motorcycle, truck or van magazine will produce advertisements from a plethora of after-market suppliers of intake and exhaust systems. Each advert will claim some performance or other benefit from fitting their system. Regulations do exist in each market for the sound pressure level or volume of sound, usually measured in decibels (db). These vary hugely with market and culture and certainly within the EU, have been tightening in recent years. According to the UK government web-site: "New cars are now required to meet Europe-wide noise limits. These have been progressively reduced from 82 decibels (dB (A)) in 1978 to the current limit of 74 dB (A) established in 1996 (VCA 2018).

<u>Taste.</u>

In automotive PQ terms, this is the least important or relevant sense and apart from its links to smell, will be disregarded in this study. Its only use is generally confined to any social eating or drinking associated with the launch, promotion or sale of a vehicle.

It is noted that the provision of cup-holders inside vehicles has caused quite a marketing war, where in particular American people-carriers and SUVs (Sports Utility Vehicles) at one time competed for the greatest number of these.

They were made to suit over-sized American fast-food outlet cup dimensions. Ever more elegant design solutions for fold-away cup-holders has created a whole new product line for suppliers to the OEMs.

In the UK, our principal contribution to the provision of food and drink furniture within cars has been the creation of 'curry-hooks' in footwells and loadspaces, so that the plastic bag containing the trays of take-aways is maintained upright to prevent spillage. It could be argued that the provision of such food and drink-related furniture could be a PQ indicator.

In recent more enlightened times towards the consumption of water in our cars, (and especially in warmer climes) it is almost expected to find allocation of space for standard one, two or even three-litre plastic bottles to be found within a normal door-pocket. Clever design can ensure that many of these features are incorporated 'for free' into plastic mouldings within the interior.

The only other and similar taste related feature or attribute is the provision of a cooled box within the vehicle in association with the air-conditioning system. As with many vehicle features, this was one which was initially found on high-end products but has now found its way down to the more prosaic models.

Appendix A2.2 The PQ Assessment zones of a vehicle

Primary Zone details

Aspect of zone	Assessment issues
Key fob - The fob is the first point of contact for the customer when viewing a vehicle.	It must: Be weighted enough to satisfy a feeling of quality without being too bulky
	Appear durable, using well shaped design (no pocket snag, with tough surfaces, plus anti-scratch)
	Use white or contrasting text to highlight fob function (black text on black surface hard to read in evening light or night time)
	Incorporate a useable, durable, door lock key (if required)

Primary Zone – Steering wheel

Steering wheel functions	Soft leather (good tactility, comforting quality)
	Good shape to thumb indents (well placed, confident grip)
	Sturdy rim diameter but comfortable for smallest team member's hand

	Scroll type radio / function controls robust and not over sensitive to accidental scrolling (Wellings, Williams and Tennant 2009)
	'Plant on' airbag conceals gaps from driver's vision
	Column has good fore and aft movement with small adjustment effort
	Column stalks within hand span of smallest team member hand (ergonomically excellent)
Steering wheel criteria	Touch – soft/hard Material – Leather/synthetic (Haverkamp 2017) Grain – deep/shallow Stitching – soft/coarse Rim size – thick/thin Rim size – diameter Rim shape – round/squared Finish – sharp/no edges Feature – functions Badge – moulded/colour/"bling" (Gloss levels of these) Colour

Primary zone - The binnacle – housing the instruments/dials

The binnacle - constantly in the drivers view	Excellent visibility of full binnacle controls through steering wheel is a minimum requirement
	Chromed rings focus the driver's attention on the dial
	Instrument cluster must be well laid out and intuitive
	White text on black has proven to be the clearest and most liked in UK PQ studies
	Text size is very important – large is easy to read.
	Interactive screen between dials should be concise with clearly visible graphics – e.g. non-blurred edges
	Night time and strong sunlight effect on illumination should not be over-looked: - to achieve a pleasing visual display - to ensure minimal reflection - to ensure none blurred graphic edges

Primary Zone – gear lever/knob/selector

The gear knob/lever/selector - has	It is **not only** a primary function for driving the vehicle; Drivers hand frequently touches the gear shift knob unknowingly for reassurance and comfort (especially in urban traffic).
	Gear shift knob requires a silky tactility to reinforce

a very large tactile input for the driver	this comfort (feels expensive, well designed and engineered) (Haverkamp 2017)
	PQ studies show that smooth metal surfaces seem to appeal the most
	Grained leather with metal and smooth plastic trim are also very popular
	Hard plastic does not satisfy any tactility considerations and should not be used except in economy class vehicles (van Laack 2014)
	Knob weight is also very important for smooth gear shift function and driver comfort

Seats - Fabric, leather or mixture of both:	Seat design should be interesting (seats comprise a large visual area of the cabin) PQ studies show that interesting, well-built seat design is a major influence in first impressions of interior (Erol et al. 2014)
	Stitching should be constant and evenly spaced – red good for sports style as Alfa
	Fabric or leather creases detract from the design (promotes feeling of poor process, no care taken in build)
	Stitching or pattern running horizontal helps to prevent pattern mismatch between cushion and squab (Alfa and Peugeot)
	Suggest that cushion to squab joint should always have cushion roll to prevent line out mismatch (Alfa, Audi, Peugeot)
	rear seat belt locks need to be well presented enabling easy lock
	seat body must be firm, yet comfortable with prominent bolster cushion, squab support and rear cushion angle
	furniture should have reasonable grain, not smooth surface
	furniture shape must ensure easy adjustment and no finger traps

Primary Zone - HEVAC controls

HEVAC controls in Instrument panel – (IP)	Equal rotary torques between HVAC and ICE controls are essential (holistic approach between component engineers required)
	Rotary peripheries need to be highly tactile – soft rubber, knurled metal
	Positive indents on rotaries give feeling of precision and quality (as in SLR camera controls) (Wellings, Pitts and Williams 2012)

	Consistent grain, colour or gloss levels between HVAC and ICE (holistic approach between component engineers)
	Modern, interesting text to screen background colours (white text on blue, white text on black etc. customer clinics analysis suggest is required. However, red text on black, black text on grey, black text on orange seen as old fashioned and not dynamic
	If touch screen PQ team suggest that HVAC controls are separate rotary dials (as Nissan Qashqai to allow easy driver usage – SAFETY ASPECT
	All IP air vent controls need to have an equal resistance required to move them for air flow direction (precision)
	IP air vent controls should never feel loose when adjusting direction (precise, well-engineered)
	IP vents with chrome surround usually imparts better quality feeling than painted silver bezels

Primary Zone – Parking brake

Parking or hand brake Note: Handbrake or EPB is ergonomically a primary zone	The handbrake / EPB must: Have good tactility on the lever or switch (underside of lever / EPB also important)
	Have no finger trap areas (especially on the lever button)
	Be easily reached from the driving position (ergonomics, functionality)
	Not be obstructed by trim (ergonomics, functionality)

<u>Secondary zone – general points</u>

	Hard plastic can be used as cost saving for IP lower, glove box, IP end finisher and closure panels
	Good 'A' surface graining can still be used in these areas so as to make them appear premium
	Jointing surfaces methodology should include tolerance disguise especially:
	IP to lower 'A' post joint (high tolerance stacks up)
	IP end finisher fit to IP (visible when door is opened)
	Glove box gap and flush (especially top edge which can be viewed from passenger position)
	Floor console joint to IP

Secondary Zone - Door casing

Door casing	Most modern European vehicle door casings are grey or black
	Chrome plated metal handles and trim give a high quality 'jewel effect', much better than silver painted plastic
	The 'jewel effect' draws customers into the vehicle enhancing the prospect of a sale
	Many OEMs now use soft feel paint on the front door casings topper and hard plastic on the rears
	Cost saving logic is that the two front seats are the mostly occupied by adults and rears used for children
	Hard plastic can be used as cost saving for non-tactile areas but for arm rest needs to be soft for comfort
	Good 'A' surface graining and gloss levels can still be used in these hard plastic areas so as to make them appear premium
	Jointing surfaces methodology should include tolerance disguise as in Skoda casing rear edge
	Bottle scoops in casings are now very common and useful stowage (as Audi A3 and VW Polo)

Secondary Zone – general

Pillars and posts	Hard plastic is generally used by OEMs for pillar and aperture trim but: Good 'A' surface graining should be used in these areas so as to make them appear premium (visually and tactile)
	Great care needs to be taken on tooling parting lines position
	If the tooling parting line position is unavoidably visible on the 'A' surface of the trim the tooling process needs to be agreed.
	Jointing surfaces methodology should include tolerance disguise:
	All upper pillar trim to headlining should have a return edge to ensure interference fit

Secondary Zone - **Headlining:**

Headlining	Material should be durable, easily cleaned, not soft nylon
	Fit to roof should be solid with no movement at front courtesy light bezel

Secondary Zone - Sun visors

Sun visors should exhibit:	Fluid open and close motion, not stiff action
	Good tactility, refined tooling parting lines along edges
	Good ergonomics with finger slot in headlining for easy access

Secondary Zone – illumination

Interior illumination colour	Welcoming, fresh, modern
	LED blue, red or white – not yellow bulb perceived as dated

Tertiary zones

Tertiary zones - Vehicle carpet or mat

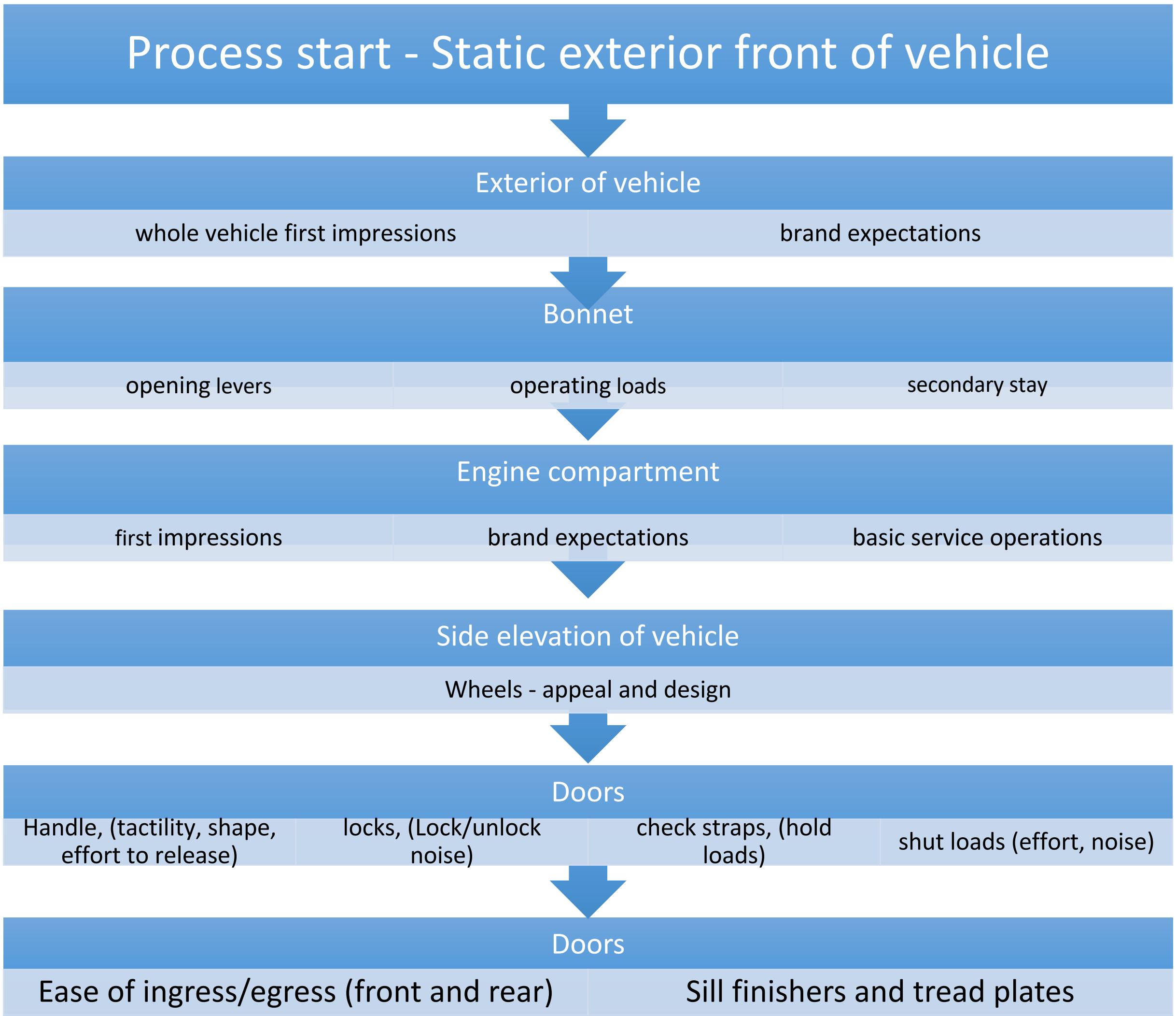
Vehicle carpet or mat	Durability should be a given for:
	Ease of cleaning, the dirt must be able to be vacuumed or brushed from a moderate pile
	Mats should match the foot space periphery without any obstruction
Fitted mats:	Mats that are retained into carpet fixings give a better quality impression than loose mats
mat design:	A brightly coloured edging strip on floor mats (as Alfa) makes an impression much greater than expected on the customer

Tertiary Zone - General

General principles	Keep visible spot welds to a minimum on door inners and door apertures
	Hide tooling parting lines from obvious view on trim
	Investigate non-painted door hinge bolts or black bolts
	No visible fixings on door casings
	Light reflection on inner front screen to be kept to a minimum
	Minimise bright work reflection from interior trim on exterior mirrors
	Ensure colour matching of light functions
	Ensure non-visible weld lines on rear lamps
	Seat sew lines need to be horizontal to avoid line out problems in vehicle assembly process

Appendix A2.3 The PQ Process as applied at the (now defunct) MG Rover Group.

(Used with permission of Liquidators, PWC and inheritors of the MG-R Quality IPR, SAIC Motor UK Technical Centre).



Interior assessment

Door casings - overall desgn

Appeal, design, fit and finish | Pocket capacity

Door casings - function

Inner release handle - front/rear (Tactility, ergonomics, access)

Door pull - front/rear

Tactility, ergonomics, access

Interior trim - whole cabin

First impression appeal, design, quality

Seats - front and rear

First impression appeal, design, quality

Seating comfort - front

Comfort, firmness, lateral and side support | Occupant headroom

Seating controls - front

Driver access, ergonomics, noise on slides | Headrest adjustment loads

Front seat belts - 'B' post height adjustment

Ergonomics, adjustment load, noise

Front seat belt buckle / stalk

Ergonomics, stalk engagement, release loads

Front seat belt

Audible/visible warning device

Seating comfort - rear seats

Comfort, firmness, lateral and side support | Occupant headroom

Seating comfort - rear seats

Leg room to front seats | Armrest comfort/position

Folding rear seats

Release conytrol ergonomics, release, release loads, lie flat

Rear seat belts

Ergonomics, stalk engagement, release loads

Fascia, glove-box and and storage

- Appeal and design
- Fit, finish, capacity, adequacy

In-car entertainment

- Appeal, design, fit,finish
- Driver access, logic of controls
- USB / ipod connection

In-car entertainment 2

- Screen clarity, colour acceptance, ease of understanding
- Speaker performance, sound quality

HEVAC System and air vents - controls

- Controls - appeal, design, overall fit and finish
- Driver access, tactility
- Vents - fit and finish, operation

HEVAC Temperature setting

- Logic, ease of understanding, positive indents, locations, line-up
- Screen clarity, colour acceptance

Cabin switches and rotaries

- Overalll integration of controls
- Movement effort consistency

Instrument binnacle

- Appeal, design fit, finish and immediate understanding

Clock

- Visivility, position, screen clarity and illumination

Steering wheel and air-bag

- Appeal, design, fit, finish and controls
- Horn operation, ergonomics and effective sound

Steering column release lever

- Driver access, shape, ease of use, any see-through condition

Column stalks and screen wash/wipe

- Stalks fit and finish, access
- Sweep of wipers, wiped area, park position, jet spray, delay

Ignition key / fob

- Size, package, weight, shape, ease of use, durability
- Load to engage / disengage if key-less

Floor / centre console

- Appeal, design, fit and finish
- Drink holder access / ergonomics (front & rear)

Cubby box

- Overall fit and finish, capacitry, ergonomics, lid opening load

Floor console ash-tray

- Fit and finish, ergonomics, opening and closing loads.

Parking brake

Handbrake gaiter appeal, design, overall fit and finish

Electronic parking brake

Appeal, design, fit and finish

Manual or automatic gear lever

Appeal, design, fit and finish

4-wheel drive controls (if applicable)

Transfer box lever / knob appeal and design	4WD electric selection switch

Floor carpet

Overall fit and finish / colour

Headling and trim

Overall fit and finish, (headlining and sun-visors)

Headling and trim

Courtesy lights - illumination, colour, switch ergonomics

Headling and trim

Sun-visor unclip, relocate load, side-swin

Sun-roof controls

Driver access, ease of use and understsnding, tactility

All post finishers

Appeal, overall fit and finish

Static evaliuation continues with exterior.....

Exterior of vehicle

Fuel flap

Release from within vehicle - position | Effort to open manual flap, open and close noise

Fuel cap

Key load, effort to remove, twist-off loads

Fuel flap inner

Cap "park" facility | Warning labels, instructions adequacy, fuel type warning

Exhaust pipe(s)

Visibility and finish of pipe

Tailgate / boot lid

Primary release lever position, release effort, lever tactility,noise

Tailgate / boot lid

Weight to lift | Taligate / boot lid pull-down handle, recess, shut effort

Load space floor / spare wheel

Securing floor in open position (easing removal of spare) ease of removal of floor and spare

Load space

Ease of loading / unloading, lip height, freedom from obstruction

Load space (cont.)

Capacity, extra compartments, load space liner material

Load spece light

Manual / automatic function, effectiveness

Laod space floor

Floor line out to folded rear seat

Parcel shelf

Ease of removal and re-fit

Jack and tool kit

Stowage and ease of use

Replacements

Ease of changing bulbs

End of static evaluation

Dynamic evaluation

Primary driving controls
Steering wheel - shape tactility, directionality | Binnacle visibility through wheel

Driving position - arm-rest
Ability to rest arm comfortably whilst driving

Pedals
General pedal operation

Foot rest
Adequate space (clearance) to pedals?

Gearbox
Gear selection, ratio suitability, notchiness

Front and rear seat belts
Seat belt audible waring device

Four-wheel drive selection (if applicable)
Drive effectiveness, ergonomics (shape, ease of use)

Directional indictators
Indicator stalk cancellation. sound leve

HEVAC system
Hot/cool efficiency

Engine
Idle speed noise | Responsiveness, performance, noise

Braking
Brake operation - load, efficiency all speeds, straight line stability

Handbrake
Feel and uality of grip, ease of use, number of clicks to hold vehicle

Electronic park brake
Logic, ease of understanding

Ride comfort
Suspension - damper performance on general road

Vehcile handling
Suspension - vehicle handling

Dynamic - cont.

Light and sight

'A' post area - Visibility at junctions

Electric mirror controls

Tactility, ergonomics, access

Interior and exterior mirrors

Rear visibility adequate?

Driving acoustics

- Tyre noise absorbtion / insulation
- Exhaust insulation
- Powertrain noise

Driving acoustics cont.

- Interior squeaks and rattle - general noise level
- Insulation from windnoise

A2.4 Automotive Manufacturers' web-sites and a search for PQ

Marque or OEM	Web site	Contents
Audi	https://www.audi.co.uk/search.html#?q=perceived%20quality&numResults=10&startResults=0	There are "0" results for: "perceived quality"
Bentley Motors	https://www.bentleymotors.com/en.html?gclid=EAIaIQobChMI54ySzdbI1wIVTpPtCh2igA2xEAAYASAAEgKFyvD_BwE	No search facility, but access to their Recalls!
BMW	https://discover.bmw.co.uk/help/search?q=perceived+quality	There are "0" results for: "perceived quality"
Citroen	http://www.citroen.com/en/	No search facility
Chrysler	https://www.chrysler.com	No search facility
Fiat	https://www.fiat.com/search?search=Perceived%20Quality	There are "0" results for: "perceived quality"
Ford	https://www.ford.com/search/?f%3AsearchInputString=Perceived+Quality&f%3Asearch=&formID=globalSearchForm	There are "0" results for: "perceived quality"
Geely	http://www.geelyauto.com.hk/en/	Site claimed 361 hits for PQ.
Honda	https://www.honda.co.uk/cars/world-of-honda/present/philosophy.html	No search facility
Lamborghini	https://www.lamborghini.com/en-en/	There are "0" results for: "perceived quality"
Lexus	https://www.lexus.co.uk/	Good section with videos on Craftsmanship, testing, development and their 'Takumi' craftsmen. Design, performance and technology.
Morgan Motors	https://www.morgan-motor.co.uk/?s=perceived+quality	There are "0" results for: "perceived quality"
Nissan	http://www.nissan-global.com/EN/QUALITY/SENSIBILITY/	Two mentions of "perceived quality".
Peugeot	https://www.groupe-psa.com/en/automotive-group/innovation/attractiveness/	Attractiveness, Lighting, Sound spatialisation & Olfactory senses
Renault	https://group.renault.com/en/search/?q=perceived quality	One mention on Ecolab car project.
Rolls Royce	https://www.rolls-royce.com/site-services/search-results.aspx?ResultPage=1&Domain=all&query=perceived%20quality&searchphrase=exact	There are "0" results for: "perceived quality"
Triumph Motorcycle	http://www.triumphmotorcycles.co.uk/search-results?searchTerm=perceived%20quality&Page=1&NumOfPages=1	There are "0" results for: "perceived quality"

Appendix A2.5 JLR PQ Job advertisement online

Some materials have been removed from this thesis due to Third Party Copyright. Pages where material has been removed are clearly marked in the electronic version. The unabridged version of the thesis can be viewed at the Lanchester Library, Coventry University.

Appendix A2.6 Visit Report – Triumph Motorcycles 14th March 2014

Ian Pogson - Coventry University
Simon Warburton – Product Manager, Product Planning Dept.

Aim of visit – to discuss the attitude of Triumph Motorcycles to PQ (Perceived Quality).

Time allotted – one hour, courteously extended to 90 minutes.

Pre-visit planned questions: -

1. Does Triumph Motorcycles measure PQ and if so, how?
2. How much effort goes in to avoiding Engineering/PQ problems at the Styling stage?
3. How does Triumph relate its impressive sales success to traditionally measured or Perceived Quality?

Brief background to Company

Triumph Motorcycles began selling new bikes in 1991, from a clean-sheet start of company and product in 1983. Manufacturing 52,000 bikes per annum, with approx. 20,000 made in the UK, there are factories in Thailand, assembly in Brazil and India will come on stream soon.
Triumph is the most popular brand of motorcycle in the UK over 500cc.
The growing range spans twin-cylinder and triple engines, in a huge variety of styles and sizes.
A 250cc single is about to be launched for the global market from India. The important, yet fickle and lucrative US market has now overtaken the UK in size.

Simon has worked at Triumph for 17 years, previously as a Design Engineer and has risen to run the Product Planning function and be a trusted spokesperson for the Company.

The Interview

1. Does Triumph Motorcycles measure PQ and if so, how?

   PQ and Sales – feeds into Brand. PQ is very closely associated with Brand.
   3 or 4 points/features on the bike are there to pull the customer in. e.g. “I can’t believe it’s not stainless”. This is a plating method on mild steel used in lieu of costly stainless.
   On new bikes, Triumph try to have focal points of PQ, e.g. specially forged stylised ends of fixings, elements of chrome, occasional covers and attempt to draw the customer’s eye.

Cost versus PQ benefit has to be considered. Some debate has taken place over the years as to how much of a “see-through” effect is maintained and how much to use stylised covers to hide elements of the motorcycle.
Harnesses tend to be covered and coloured wires are hidden.

What will influence customer versus what is feasible and cost-efficient is a familiar debate.

2. How much effort goes in to avoiding Engineering/PQ problems at the Styling stage and do you conduct Benchmarking?

Yes, Triumph looks at the Engineering side of competitors for new ventures (to Triumph, e.g. for the new single-cylinder machine and shaft and belt-drives for recent new bikes). For example, Chassis Attributes have come from B/M PQ evaluations.

Triumph does not have their own Styling studio but use trusted outside design houses. They still create resin models and judge PQ issues based on this first one.
Product Planning Dept. “calls the shots” on styling direction and sign-off.

The Company places great store against using internal experienced motorcyclists. Dealers and distributors are asked for input from all markets, however some travelling outside UK is necessary by PP Dept. to see for themselves. Occasionally in-market they “do pick up some nuggets/light-bulb moments”.

They rely on local Triumph staff to discuss and formulate local needs.

PP Dept. then takes a view on what is presented.
Across all markets people have similar views; tend to be differences on colour and style, for example -Americans have almost uniformly LOUD pipes. Why?

3. How does Triumph relate its impressive sales success to traditionally measured or Perceived Quality?

Triumph has lots of Design procedures, “Design Top Tips and Accumulated Knowledge”. All Engineers when designing a new machine use these.

Triumph insists upon build quality, gaps and flushes as on cars, but exercise special care on panels and edge feel, even on self-coloured parts. These are much more likely to be touched and removed or cleaned around on a motorcycle than a car.

Some lessons had to be learned on switch cubes (HMI issues) and mirrors, display technology, etc.

Despite having a reputation for customer-delighting soundtracks, Triumph are now putting even more effort into NVH.

Lessons are continually being learned, e.g. from Recalls. Past problems are noted in the PDS, so mistakes are not repeated.

Conclusion.

This was an excellent opportunity to hear first-hand from an Engineer-turned-Product-Planner about the inner workings of a well-respected British manufacturer.
The impression of a solid range of products was reinforced by a Company Representative who was open, honest and constructive with his commentary.
The interviewer would like to thank Triumph for this opportunity.

Ian Pogson CEng FIET

Triumph Motorcycles
Normandy Way
Hinckley
Leicestershire
LE10 3BZ

01455 453005
www.triumphmotorcycles.com

Chapter 3 Appendices

Appendix A3.1 Steenkamp's Hypotheses in full

Ref. no.	**Hypothesis details**	**Upheld/not by empirical study**
H_1	"Quality attributes act as intervening variable, mediating the effects of quality cues on PQ judgements."	Upheld
H_2	"Experience attributes are weighted more heavily in the formation of PQ judgements than are credence judgements."	Upheld
H_3	"Consumers are more able to use quality cues in inference processes with respect to experience attributes than with respect to credence attributes."	Upheld
H_{4a}	"The higher the predictive value of a cue, the more important that cue is in the formation of PQ judgements."	Upheld
H_{4b}	"The higher the confidence value of a cue, the more important that cue is in the formation of PQ judgements."	Upheld

H_{4c}	"Intrinsic cues are more important in the formation of PQ judgements than extrinsic cues."	Upheld
H_5	"The intervening role of quality attributes in the quality perception process is greater for consumers with much experience with the product in question than for less experienced consumers."	Not upheld
H_6	"The intervening role of quality attributes in the quality perception process is greater for quality-conscious consumers than for consumers who are less quality-conscious."	Upheld
H_7	"Consumers experiencing high risk in evaluating the quality of the product alternatives have used fewer quality cues in the quality perception process than consumers experiencing low risk."	Upheld
H_8	"Higher-educated consumers use more cues in the quality perception process than lower-educated consumers."	Partially upheld
H_9	"Cue interactions are more numerous in the quality perception process of higher-educated consumers than in the quality perception process of lower-educated consumers."	Partially upheld

Appendices A3.2 to A3.6 – samples from Matrix

There now follows a series of screen-shots of the Reading Matrix. The first five show how the matrix was populated and maintained as a research tool. The colour key is shown in the header to each image. VIP's (Very Important Papers) are shown in yellow.

Also in this section are two images of the table created to check that all references had been used as required upon which to build and back up the research undertaken. The sheets show a tick mark for each reference number (this identity being automatically allocated by the RefWorks legacy software) that was used in the work. Any critiques that were created are also recorded and check-marked. The final sample is of a full critique using the Coventry University CAW (Centre for Academic Writing) process.

Appendix A3.2 Sample of Matrix – 1 Body and Design

Ian Pogson Reading Matrix for PhD in "The Measurement of Perceived Quality in the Automotive Industry"

Engineering CoCs			Paper title	Ref. No.	Short description	ISP2 Critique and summary	Relevance to PhD studies - Thesis area	Methodology	Perspective			Metrics			
CoC	Sub-catego	Note				Green = critique written	Green = relevant Amber = some relevance		User	Mix	Enginee r-ing	Subjective	Objective	Qualitative	Quantitative
BO			Retrospective Analysis & Evaluation of Non-nominal Visualisation Soderberg R 2010	5	Abstract only	n.a...	Automotive PQ	Industrial study of PQ in Volvo Cars.			E	S		Q	
BO	Panels		Detecting subtle cosmetic defects in automotive skin panels	68	Cosmetic defects are hollows – approx. 30-50micrometres in depth; a small deviation from form, which shows up post-painting. PQ is affected as a result. The paper proposes three aspects to the problem; springback, optics and ability to detect by eye. The paper then proposes a way of using signal processing techniques to ascribe a value to the optically detected distortion.			FE then auditor assessment			E		O	Q	
BO	Panels		Predicting the occurrence of skin defects in auto panels Hazra S 2013	108	Paper looked at 30 - 50 mm long defect which were <50 microns deep.	no	Automotive PQ	Used FE and wavelet transform.			E		O		Q
CH															
Design			A cross-cultural study of users' craftsmanship perceptions in vehicle interior design. Petiot J-F 2009	7	2009 paper comparing French and American attitudes to interior PQ. Useful set of attributes from JCL used.		Automotive PQ	Student survey	U			S		Q	
Design			Perceived Quality in Design Management Kataoka A 2004	38	2004 paper from the Nissan Design Centre in Kanagawa on how the Company was trying to improve brand image through PQ. A short, two-page paper with very little new in it, not the hoped-for realisation of the Nissan recipe for their obvious success.	No	Automotive PQ	Process review			E	S		Q	
Design			The Eight Dimensions of Quality - A Designer's point of view David Garvin	61	A check-list by a notable Designer on Design for Quality- he suggested 8 dimensions.	no - short article	Quality Definition	Observation		M		S		Q	

Appendix A3.3 Sample of Matrix – 2 Design showing VIP's

Ian Pogson Reading Matrix for PhD in "The Measurement of Perceived Quality in the Automotive Industry"

Engineering CoCs			Paper title	Ref. No.	Short description	ISP2 Critique and summary	Relevance to PhD studies - Thesis area	Methodology	Perspective			Metrics			
CoC	Sub-catego	Note				Green = critique written	Green = relevant Amber = some relevance		User	Mix	Enginee r-ing	Subjective	Objective	Qualitative	Quantitative
					by customers, relating these attributes to engineering facets.										
Design	HMI	VIP	Desmet, P. and Hekkert, P. (2007) 'Framework of Product Experience	127	Framework for experiences in HMI, considering aesthetic (governing delight/disgust) experience, experience of meaning (assigning personality or symbolism) and emotional experience (love/hate – from the appraisal process). Each has levels below.			A couple of diagrams created to show relationships between effect and emotion, user and experience and appraisal components.	U			S		Q	
Design	VoC		Consumer Satisfaction and Perceived Quality: Complementary Or Divergent Constructs?	130	Considered opposing views in research on how PQ/satisfaction affects conduct. Need for a model to show interaction of PQ and satisfaction. Attempts to illustrate the inter-relation of PQ, satisfaction, perceived situational control and behavioural intentions. Results show PQ affects satisfaction and this in turn affects subsequent behavioural intentions.		Quality Definition	Questionnaire	U			S		Q	
Design	Strategy	VIP	Surprise as a Design Strategy	133	No written abstract, but descriptive article reviewing Design Strategies leading to surprise and whether this is desirable or not. Good paper, though not mentioning PQ directly, covers tactility, colour, surprise, delight, emotion, etc.		Def and VOC	Survey and descriptive piece	U			S		Q	
Design		VIP	Towards an Experiential Perspective on Product Quality	152	UX is an attempt to assess the interaction between product and user, but concentrating on the person.			Questionnaire	U			S		Q	
Design	Design & Emotion	VIP	Special Issue Editorial : Design and Emotion	154	Summary of a decade of research on Design and Emotion		Def. and VOC	Not a technical paper, but an introduction to a series of eight papers presented at the 10th Anniversary of the Design and Emotion conference series.	U			S		Q	
Design			Richard Barrett Empathic Design Tutor	155	This is a brochure detailing Dr. Richard Barrett's work from Cranfield and Nissan. Should you wish to view a copy, please contact Ian Pogson who will put you into communication with the author. It is quite relevant to the subject of PQ.			Observation		M			O	Q	Q

Appendix A3.4 Sample of Matrix – 3 Electrical Eng. and Interior Trim

Ian Pogson Reading Matrix for PhD in "The Measurement of Perceived Quality in the Automotive Industry"

Engineering CoCs: CoC	Sub-catego	Note	Paper title	Ref. No.	Short description	ISP2 Critique and summary (Green = critique written)	Relevance to PhD studies - Thesis area (Green = relevant Amber = some relevance)	Methodology	Perspective: User	Mix	Engineer-ing	Metrics: Subjective	Objective	Qualitative	Quantitative
EE	Instruments and display	also in Design	Towards personalisation of the driver environment-investigating responses to instrument cluster design Tractinsky N 2011	93	Two experiments - 1 with real IPKs and 2 with CAD images. Subjects asked to rate preferences.		Automotive PQ	repeat							
EI			Analysis of car door closing sound quality Parizet, Gyader, Nosulenko	50	Door shutting sound affects the image and PQ of a car. Three experiments were carried out on 16 cars from 8 manufacturers. Two timbre parameters came out strongly – frequency balance and cleanness of sound. Loudness did not feature.		Automotive PQ	Experimental with real door closing tests		M		S	O	Q	Q
EI	Hard Trim		Optimum design of guide positions for decreasing the Permanent Deformation of a Cockpit Module Kim B Y 2012 - plastic trim noise (Hyundai/Kia)	63	2012 - Interior plastic parts are major contributors to PQ. There is a link to PQ and noise between plastic parts in a cockpit. There is therefore a need for appropriate simulation to address this. Abaqus and iSight were evaluated.		Automotive PQ	Assessment of five three-dial rotary HEVAC controls from B-segment cars.		M		S		Q	
EI	Rotary Dials - heater controls		Characterising the experience of interaction - an evaluation of automotive rotary dials. Wellings T 2012	69	An excellent review of small-car three-dial heater controls. Useful in its own right, but also to show attribute date for secondary controls.		Automotive PQ	Observation of and comments from users in-car and on bench to check on contextual effect.	U			S		Q	
EI	Lighting		Forward-looking interior light LED solutions with LED Technology. Denkelmann R 2008	70	2008 Delphi view - The paper aims to show the pros and cons of using High Power LEDs, the electrical control and thermal management necessary to gain the best reliability out of these units and also consideration of the manufacturing and assembly of such devices. A view of the future (from a 2008 point of view) is also given.		Automotive PQ	Technical guide to LEDs and their use in cars. Heat dissipation, simulation and solutions for dimming, etc.		M			O	Q	Q

Appendix A3.5 Sample of Matrix – 4 Engineering Quality showing VIP's

Ian Pogson Reading Matrix for PhD in "The Measurement of Perceived Quality in the Automotive Industry"

Engineering CoCs: CoC	Sub-catego	Note	Paper title	Ref. No.	Short description	ISP2 Critique and summary (Green = critique written)	Relevance to PhD studies - Thesis area (Green = relevant Amber = some relevance)	Methodology	Perspective: User	Mix	Engine-ering	Metrics: Subjective	Objective	Qualitative	Quantitative
S&M			Triumph Motorcycles Spirit magazine	164	NY kitchen wall poster about PQ	No short article	Brand and PQ	Survey	U			S		Q	
S&M		VIP	Why we love or hate our cars: A qualitative approach to the development of a quantitative user experience survey	179	Paper looks at a more ecologically sound method to create questionnaires to measure UX. Ten drivers were interviewed in their cars and 71 response categories recorded and analysed to grasp their normal verbalisations of automotive experiences. On-line 538 people in Brazil responded to a resulting survey using sentences from the 71. This produced a highly reliable appraisal.	No short article	Brand and PQ	Report	U			S		Q	
S&M			User Experience Evaluation Methods: Current State and Development Needs	182	UX is a prime focus for product design and assessment. Paper reports on several years of evaluating 123 UX evaluating methods and analysed 96 of the best. Shows a need for further research.		Brand and PQ	Report		M		S		Q	
S&M		VIP	Attractive quality and must-be quality	249	Kano methodology		Current PQ	Survey and questionnaires		M		S		Q	Q
S&M		VIP	Product Quality from the Customers' Perspective–Systematic Elicitation and Deployment of Perceived Quality Information	257	Product Quality lies in the eyes of the beholder." How to objectify quality judgements and structure PQ from customer perspective. Used a survey looking at attributes.		VOC	Surveys, focus groups, b/m, conjoint analysis		M		S		Q	
S&M			Global sales	272	Sales figures	n.a.	Automotive PQ	Sales figures	U				O		Q
S&M			Brexit and diesel concerns drive UK car-production down 46 per-cent	273	Sales figures	n.a.	Automotive PQ	Sales figures	U				O		Q
								THIS COUNT	141	130	11	182	147	254	82

Appendix A3.6 Sample of Matrix – 5 Sales & Marketing and total counts

Ian Pogson Reading Matrix for PhD in "The Measurement of Perceived Quality in the Automotive Industry"

Engineering CoCs			Paper title	Ref. No.	Short description	ISP2 Critique and summary	Relevance to PhD studies - Thesis area	Methodology	Perspective			Metrics			
CoC	Sub-catego	Note				Green = critique written	Green = relevant Amber = some relevance		User	Mix	Engine-erin	Subjective	Objective	Qualitative	Quantitative
S&M			Nobody loves cars like Generation Y	162	Short article on commercial PQ	No short article	Brand and PQ	Survey	U			S		Q	
S&M			Triumph Motorcycles Spirit magazine	164	NY kitchen wall poster about PQ	No short article	Brand and PQ	Survey	U			S		Q	
S&M		VIP	Why we love or hate our cars: A qualitative approach to the development of a quantitative user experience survey	179	Paper looks at a more ecologically sound method to create questionnaires to measure UX. Ten drivers were interviewed in their cars and 71 response categories recorded and analysed to grasp their normal verbalisations of automotive experiences. On-line 538 people in Brazil responded to a resulting survey using sentences from the 71. This produced a highly reliable appraisal.	No short article	Brand and PQ	Report	U			S		Q	
S&M			User Experience Evaluation Methods: Current State and Development Needs	182	UX is a prime focus for product design and assessment. Paper reports on several years of evaluating 123 UX evaluating methods and analysed 96 of the best. Shows a need for further research.		Brand and PQ	Report		M		S		Q	
S&M		VIP	Attractive quality and must-be quality	249	Kano methodology		Current PQ	Survey and questionnaires		M		S		Q	Q
S&M		VIP	Product Quality from the Customers' Perspective–Systematic Elicitation and Deployment of Perceived Quality Information	257	Product Quality lies in the eyes of the beholder." How to objectify quality judgements and structure PQ from customer perspective. Used a survey looking at attributes.		VOC	Surveys, focus groups, b/m, conjoint analysis		M		S		Q	
S&M			Global sales	272	Sales figures	n.a.	Automotive PQ	Sales figures	U				O		Q
S&M			Brexit and diesel concerns drive UK car-production down 46 per-cent	273	Sales figures	n.a.	Automotive PQ	Sales figures	U				O		Q
								THIS COUNT	142	132	11	184	149	256	83

Appendix A3.7 Matrix and Critique check – 1

Ian Pogson Reading Matrix for PhD in "The Measurement of Perceived Quality in the Automotive Industry"

Engineering CoCs			Paper title	Ref. No.	Short description	ISP2 Critique and summary	Relevance to PhD studies - Thesis area	Methodology	Perspective			Metrics			
CoC	Sub-catego	Note				Green = critique written	Green = relevant Amber = some relevance		User	Mix	Engine-erin	Subjective	Objective	Qualitative	Quantitative
EQ		VIP	Final vehicle product audit methodologies within the automotive industry Turley, Williams Tennant 2007	265	PQ has changed from simple Q&R attributes to touchy, feely stuff, taken as craftsmanship. The paper surveys OEM Final Vehicle Product Audit (FVPA) schemes to see how it is measured and applied to the PD and NPI processes. Links are sought between FVPA, suppliers' quality and craftsmanship via questionnaires		Automotive PQ	Questionnaires		M		S	O	Q	
EQ			Web-site from IET about Chinese customers not liking new car smells.	266	Web-site from IET about Chinese customers not liking new car smells.	n.a.	Automotive PQ	Report	U			S		Q	
EQ			Product and PQ Audit Process	275	MG Rover Perceived quality process	n.a.	Automotive PQ	Process		M		S	O	Q	Q
		VIP	Perceived Quality Attributes Framework and Ranking Method.	276	PQ is important attribute in auto ind. The paper looks to connect engineers to PQ attributes and rank them by importance. A framework, the PQF is proposed. Interviews with Euro and NA experts and PQ Engineers used.		Automotive PQ	Framework		M		S	O	Q	
EQ		VIP	Perceived Quality Attributes Framework and Ranking Method.	277	New framework to define PQ.		Automotive PQ	Interviews, Survey		M		S		Q	
EQ			ISO 9001:2015	278	Quality standards	n.a.	Definitions	Quality Standards		M			O	Q	
EQ			Adoption of ISO9001	279	Wikipedia view	n.a.	Definitions	Quality Standards		M			O	Q	

RefWorks checks of Matrix data 289 References

Ref. No. from RefWorks	In or out	Critique?	Ref. No. from RefWorks	In or out	Critique?	Ref. No. from RefWorks	In or out	Critique?	Ref. No. from RefWorks	In or out	Critique?	Ref. No. from RefWorks	In or out	Critique?	Ref. No. from RefWorks	In or out	Critique?	Ref. No. from RefWorks	In or out	Critique?
1			51	✔		101			151			201	✔		251	✔		301	✔	✔
2	✔		52	✔		102	✔		152	✔	✔	202	✔		252	✔		302	✔	
3	✔		53	✔		103			153			203	✔		253	✔	✔	303	✔	
4			54			104			154	✔	✔	204			254			304	✔	
5	✔		55	✔	✔	105			155	✔		205	✔	✔	255	✔	✔	305	✔	
6			56			106	✔		156			206	✔	✔	256	✔	✔	306	✔	
7	✔	✔	57	✔		107			157	✔		207	✔	✔	257	✔	✔	307	✔	
8			58	✔		108	✔		158	✔		208	✔	✔	258	✔	✔	308	✔	
9	✔	✔	59	✔	✔	109	✔	✔	159	✔		209	✔	✔	259	✔	✔	309	✔	
10	✔		60	✔		110	✔		160	✔		210	✔	✔	260	✔	✔	310	✔	
11			61	✔	✔	111	✔	✔	161			211	✔	✔	261	✔	✔	311	✔	
12	✔		62	✔	✔	112	✔	✔	162	✔		212	✔		262	✔	✔	312	✔	
13			63	✔	✔	113	✔	✔	163	✔		213	✔		263	✔	✔	313	✔	
14	✔		64	✔		114	✔		164	✔		214	✔		264			314	✔	
15	✔	✔	65	✔		115			165	✔		215	✔		265	✔	✔	315	✔	
16	✔		66	✔	✔	116	✔	✔	166	✔		216	✔		266	✔		316	✔	
17			67	✔		117	✔		167			217	✔		267	✔		317	✔	
18			68	✔		118	✔		168	✔	✔	218	✔	✔	268	✔		318	✔	
19			69	✔	✔	119	✔	✔	169	✔		219	✔	✔	269	✔		319	✔	
20			70	✔		120			170			220	✔		270	✔		320	✔	p
21			71	✔	✔	121	✔	✔	171	✔	✔	221			271	✔		321	✔	p
22	✔		72	✔		122	✔		172			222	✔		272	✔		322	✔	
23	✔	✔	73	✔	✔	123	✔	✔	173	✔	✔	223	✔		273	✔		323	✔	
24	✔	✔	74	✔	✔	124	✔	✔	174	✔	✔	224	✔		274	✔		324	✔	
25	✔	✔	75	✔	✔	125	✔	✔	175			225	✔		275	✔		325	✔	
26	✔	✔	76	✔		126	✔		176			226	✔		276	✔	✔	326	✔	
27	✔		77	✔	✔	127	✔	✔	177	✔		227	✔		277	✔		327	✔	
28	✔		78	✔	✔	128	✔	✔	178	✔	✔	228	✔		278	✔		328	✔	
29	✔	✔	79	✔		129			179	✔	✔	229	✔		279	✔		329	✔	p

Appendix A3.8 Matrix and Critique check – 2

RefWorks checks of Matrix data 289 References

Ref. No. from RefWorks	In or out	Critique?	Ref. No. from RefWorks	In or out	Critique?	Ref. No. from RefWorks	In or out	Critique?	Ref. No. from RefWorks	In or out	Critique?	Ref. No. from RefWorks	In or out	Critique?	Ref. No. from RefWorks	In or out	Critique?	Ref. No. from RefWorks	In or out	Critique?
30	✔		80	✔	✔	130	✔	✔	180	✔		230	✔		280	✔		330	✔	
31			81	✔		131	✔		181	✔	✔	231	✔		281	✔		331	✔	
32	✔	✔	82	✔		132	✔		182	✔	✔	232	✔		282	✔		332	✔	p
33	✔	✔	83	✔	✔	133	✔	✔	183	✔	✔	233	✔		283	✔		333	✔	
34	✔	✔	84			134	✔		184	✔	✔	234	✔		284	✔		334	✔	
35	✔		85	✔	✔	135	✔	✔	185	✔		235	✔		285	✔		335	✔	p
36			86	✔		136	✔		186			236	✔		286	✔		336	✔	p
37	✔		87	✔		137	✔		187	✔		237	✔	✔	287	✔		337	✔	
38	✔		88			138			188			238	✔		288	✔		338	✔	
39	✔	✔	89	✔		139	✔		189			239	✔		289	✔		339	✔	
40	✔		90	✔		140	✔		190			240	✔		290	✔		340	✔	
41	✔		91			141	✔		191			241	✔		291	✔		340	✔	
42	✔		92	✔		142	✔		192	✔		242	✔		292	✔		341	✔	
43	✔	✔	93	✔		143			193			243	✔		293	✔		As at 20190611		
44	✔		94	✔		144	✔		194	✔		244	✔		294	✔				
45	✔		95	✔		145	✔		195	✔		245	✔		295	✔				
46	✔		96	✔		146	✔		196	✔		246	✔		296	✔				
47	✔		97	✔		147	✔		197	✔		247	✔		297	✔				
48	✔	✔	98	✔		148	✔		198			248	✔		298	✔				
49	✔		99	✔		149	✔		199	✔		249	✔		299	✔				
50	✔	✔	100	✔		150	✔	✔	200	✔		250	✔		300	✔				
	37			45			40			34			48			48			41	
																		Total refs.	293	

Appendix A3.9 Example of completed Critique

<u>Paper critique - 222</u>

Stylidis, K., Wickman, C., and Söderberg, R. (2015) 'Defining Perceived Quality in the Automotive Industry: An Engineering Approach'. *Procedia CIRP* 36, 165-170

<u>Abstract</u>

Quote – "Perceived Quality is one of the most important factors underlying success of car manufacturers today". Literature from psychology, marketing and consumer research, but not much on automotive except in early stages. "… no theoretical framework has yet been compiled that combines customer view on perceived quality and the engineering prospects of this broad term". Paper proposes a common terminology and PQ definition for the industry.

<u>Keywords</u>

PQ; product quality; manufacturing quality; information and knowledge management in product development

<u>Paper critique</u>

<u>Paper aims</u>

The aim is to come up with a way to combine objective assessment and quantification of subjective attributes regarding PQ.

<u>Methodology</u>

Literature review, plus a couple of models showing how TPQ (Technical Product Quality) and VPQ (Value Based Perceived Quality) combine to achieve the aim.

A couple of useful schematics showing Quality dimensions and approaches from literature and the terms used therein.

Created a very useful block diagram showing TPQ within VPQ and all constituent attributes (inc. sensual, craftsmanship, NVH, material, paint, etc.)

<u>Results and Discussion</u>

Subjective nature of attributes and little data showing their importance to the customer make it difficult to assess in early D&D.

PQ commonly cited, but little research on what it means to Engineering, or how to engineer for it. PQ definitions are many and varied, sometimes conflicting.

Still no clear path on which PQ attributes to concentrate upon and when in product development.

<u>Conclusions</u>

PQ and product quality do not cover all elements. The paper brings together terminology into a framework under VPQ – Value Based PQ. However, this is only early stage research and PQ understanding is not complete.

<u>Review</u>

1. What are researchers trying to find out? A way to combine objective assessment and quantification of subjective attributes regarding PQ.
2. Why is the research so important? There isn't much available and it complements my own.
3. What things were measured? Nothing, but definitions.
4. What were the results? A couple of useful frameworks.
5. What do the authors conclude? PQ and product quality do not cover all elements. What factors do they attribute to their findings? Difficulty in defining PQ attributes at all stages of D&D.
6. Can you accept the findings as true? Good stuff. Warrants further research.

(Stylidis, Wickman and Söderberg 2015)

Chapter 4 Appendices

A4.1 Survey questions

A4.2 Survey results in Pie-carts, where useful to show response split.

A4.3 Statistical analysis

A4.4 Mann-Whitney U-test assumptions

Appendix A4.1 – Survey questions and example from pilot

The questions asked in this survey are shown in full below:

1. Are you aware of the PQ process in the Company?
2. Are you aware of the current PQ Benchmark reports and do you know where to find them?
3. If you know where the PQ reports are held, or have seen one, do they help you design PQ into our products?
4. Do you think that PQ should be part of the VTS (Vehicle Technical Spec.)?
5. Where in the NPIP (New Product Introduction Plan) should Perceived Quality targets be set?
6. Who should be responsible for delivering PQ in our products?
7. How important do you rate PQ in relation to other targets?
8. Are you aware of any PQ targets for either system or components?
9. Would some form of PQ "Blueprints" be useful? e.g. A Designer's Guide to PQ?
10. How would you like PQ and Benchmark data presented to you?
11. Would you agree with a target for the achievement of PQ - would it help? If so, should it be a deliverable?
12. If you had a target for PQ, such as "Best-in-class", would it help you design to the target?
13. We currently rate cars in the Perceived Quality Studies on a 1 to 10 scale. Does this represent a valid assessment scoring regime?
14. Should we place less reliance upon benchmarking cars and look elsewhere?

15. How much extra would you pay for good PQ, in say a car or household product? (This was a general question aimed at the Engineers as normal purchasers of everyday goods).

Question	Comment
1	**Are you aware of the Perceived Quality process in the Company?**
	I have some knowledge and awareness
	I've heard of it but don't know the details of it.
2	**Are you aware of the current PQ Benchmark reports and do you know where to find them?**
	I am aware of them but I have never had cause to look for them?
	I guess they are reports done by Quality team?
3	**If you know where the PQ reports are held, or have seen one, do they help you design PQ into our products? Use the Comments box if you know how Benchmarking information is**
	No vehicle level targets to deliver PQ. PQ vehicle level targets are not monitored.
	programmes.
	No process that I am aware of.
	Apart from comments and limited involvement of PQ engineers at the design stage (through not being invited I must add!) we tend to ignore this valuable feedback on each project
	I've no knowledge of or introduction to them, beyond knowing that they are compiled.
	Not applicable as unknown to me
	income v. cost ratio

4	**Do you think that PQ should be part of the Vehicle Technical Standard?**
	We need defined targets for PQ
	TOUCH, FEEL, EFFORTS etc. - MASSIVELY IMPORTANT FOR CUSTOMER PERCEPTION AND ITS CAN COST LITTLE
	Not seen a Vehicle Technical Standard. But sounds like it should be rolled out with buy-in from ALL parties.
	I think PQ should be more organically connected with development process rather than documented drily.
	The company still seems to be particularly weak on its Vehicle Technical Standard preparation, while much of the public and press perception of our cars relates to the tactility, user friendliness and general sense of harmony and well being that is sorely missing while more apparent in say, the days of MG Rover despite all
	It would be a good way to ensure some good practice is adhered to. But PQ can be dependent on the design selected - e.g. lower door cladding on SUV can aid step over and avoid soiling on entry.
	Not sure how it can be specified, but I'm sure it should be.
	For a given program and particularly a given brand, the PQ target should be inherent in deciding budget
5	**Where in the NPIP (New Product Introduction Process) should Perceived**
	In the early phases (MS1) benchmarking is conducted as part of the Product Attribute events. Targets are
	As early as possible, define competitors, benchmark them with A-gateways. MS2 finalised targets within Vehicle Technical Standard.
	It should be baked into the process from concept to production, we need to stay in front of or at least keep up
	I do not know what the NPIP is.
	BUILT IN EARLY
	Continuous improvement should be employed through all stages. With each refinement of the design will come a new requirement to adapt the PQ requirements.
	Any projects should have set target from the very beginning of the programme.
	At the start but I don't know which box to tick, sorry.
	Early as possible.

6	**Who should be responsible for delivering PQ in our products?**
	Design, Project Manager, Marketing, COC - Managed by attribute owner
	EQ
	EVERYONE
	Needs to be lead from the very top of the company
	TEAM EFFORT
	Everyone, but should be led by CoC Director/Workstream Leader
	Everybody with input into those parts attracting PQ assessment (inc. suppliers!)
	Everyone
	Everyone should play a part, sooner rather than later.
	All of us
	All of the above.
	All the above
	All
	Actually everyone.
7	**How important do you rate PQ in relation to other targets?**
	PQ sells cars, drives desirability and perceived value.
	Dependent on vehicle sector
	sales
	Tempted to say over-riding, but real substance is even more important (integrity).

8	**Are you aware of any PQ targets for either system or components?**
	Not aware
	Never seen any targets laid down
	No idea, sorry
	Unaware of PQ targets
	Only Vehicle Technical Standard targets
9	**Would some form of PQ "Blueprints" be useful? e.g. A Designer's Guide to**
	Not sure on the question
	Component / system related guidelines.
	ISSUE TO ALL COLLEAGUES
	Case studies are very beneficial where it can be shown PQ has resulted in improvements.
	quite sure about Blueprints.
	Definitely be helpful.
	The Auditor has built up some good process for design to use. He is a good PQ champion. However, ensuring these ideas are adhered to can only happen if Product Executive take it on board.
10	**How would you like PQ and Benchmark data presented to you?**
	Objective targets for systems and at component level. Clear requirements to deliver required level of PQ.
	Current data doesn't do this.
	Need to ask the PQ customers!! Chief Engineers for instance.
	Initially, benchmarking of realistic competitor vehicles (Market domestic/JV and not Mercedes et al!)

11	**<u>Would you agree with a target for the achievement of PQ - would it help? If so, should it be a Gateway deliverable?</u>**
	Closed Questions - no comments
12	**<u>If you had a target for PQ, such as "Best-in-class", would it help you design</u>**
	Closed Question - no comments
13	**<u>We currently rate cars in the Perceived Quality Studies on a 1 to 10 scale. Does this represent a valid assessment scoring regime?</u>**
	A 'Subjective' review will obviously depend on the person reviewing the car
	like, acceptable, dislike
	Current system doesn't work all cars within a very small spread. It does not reflect the actual importance.
	A number doesn't tell a component engineer or design how to engineer the part. A number could be used but you also need a description of what to do.
	TOO VAGUE MIGHT HAVE GREAT SEATS BUT CRAPPY ENGINES
	Maybe we need "subject" experts for each area of the car to do an objective rating then general people to carry out the subjective assessment and compare the results
	supplier
	Use a Likert system as we have introduced for vehicle assessment

	<u>For the penultimate question, let's be contentious. It could be argued that real customers do not necessarily take our view of benchmarking against other cars, but take their PQ standards from other influences in</u>
	Yes definitely! PQ is derived from customer experiences. Customers are not automotive engineers.
	You need to do both if you want to keep up. You have to be careful with consumer products as the lifecycle is much shorter leading to a dated look.
	for instance.
	Reviewing other products for PQ appeal would allow the business to get a real understanding of PQ. Benchmarking vehicles is the best way of assessing our competitors though
	A combination of both
	A PQ Benchmark can be from any product or idea in my opinion.
	Both should be taken into account depending on the system. I.e. The quality of the UI on a sat nav should be benchmarked against mobiles and the interior against other vehicles.
	PQ benchmarks should not be related just to cars, the materials that are used are not unique to the car game. Clearly piano black originated elsewhere, the same with suede or leather, HMI etc. etc.
	NO WE ARE STILL PLAYING CATCHUP AND ALWAYS WILL WITH SUCH A SMALL TEAM
	yes, benchmarking is all about yesterday and someone else's innovation
	'Keep Up'
	Yes, it's all about the buying experience - the overall package, ease of buying, ease of use (intuitive?) and if something goes wrong - how easily and quickly is the problem rectified
	look elsewhere
	they both need to be reviewed
	Good question and valid. Maybe focus on those areas important to majority of buyers in a dealership. (e.g.. highest volume demographic). PQ could then be tailored to each market segment (small car and BP
	Consider both
	PQ is subjective and there is no way we can measure it up 100%. I do agree we need to look at what's around us as well as benchmark cars. At the end of the day, consumer trends tend to change quickly and due to the
	I think a mix of the two would be good.
14	PQ for the customer begins before they drive away in their car: it begins with PQ impressions gained by the press, the atmosphere in the dealership, the attitude of the staff, the type of test drive offered and the finance deal made. Only then does the car's PQ begin to matter, and the entire experience must be harmonious, so
	No. Reliance on benchmarking cars as well as other influences in the right way forward.
	went to a restaurant and had poor customer service I wouldn't go back even if it was the best food in the
	I would agree when considering in car entertainment and user interfaces
	Both
	should look at all relevant commodities that effect our customers perception
	No, vehicle benchmarking is key to ensure you have a view of where your competitors are going and establish trends for market sectors. This enables you to project where you need to be against current competition in
	This sounds like a sensible suggestion
	trends are developing in communication etc.
	Yes, we should use the best from all sorts of products
	I think as engineers we place too higher focus on issues/functions that most ordinary customers do not even consider. I remember tell my wife about all the fantastic features that we in EE had implemented in our last car and she could not have cared less... Mrs. C: "Does it get me from A to B safely, in reasonable comfort, economically?" MrC ..."but you can select how long the lights stay on for after you've left the vehicle..etc.. etc." MrsC "Not bothered I'll never us it!"
	no
	Not sure
	our competitiveness.
	to excel in, for each Company product. e.g. steering wheel, centre stack, IPK.
	Does benchmarking in general limit our ambitions? I agree that customers may be strongly influenced by other products and services outside of the automotive industry, but perhaps we should start with the customer and
	No more important to deliver our own product quality not rely on external effects to sell our vehicles
	I agree that we should consider both
	Agree. We should take both inspiration and standards from elsewhere.
	Benchmarking of cars still has its place.
	Goo[illegible] Tesla are all making forays into the auto industry. They will benchmark all sorts of industries in their development and have thinking which is unclouded by the conventions of a 100+ year old
	yes, we should engage the top suppliers

15	**How much extra would you pay for good PQ, in say a car or household**
	example perfumes.
	Audi to Ford around 10% difference,i would pay this.
	Difficult to say - depends on asking price
	25%
	Impossible to be specific but it would be some percentage greater.
	I don't think you can quantify the PQ add on, there are two ways of looking at it. There are things that you choose NOT to purchase due to PQ, example might be when choosing a torque wrench - the draper will do the
	YOU GET WHAT YOU PAY FOR- PEANUTS=MONKEYS
	Good PQ should be engineered in for zero cost
	impossible to define, if the quality is exceptional then you would pay a premium for it.
	you always ballace cost againt your percieved quality
	Good PQ for the same or lower price would swing the deal for me.
	I would buy second hand car with better PQ than brand new car with bad PQ!
	At least 10-20% for the right PQ
	None - it should be taken a read.
	Nothing it should be the price of entry
	None. For modern products it should be a given
	Depends on desirabilty of the product
	Should be a given
	Actual quality more important than perceived quality
	I cannot put a price on this, but would expect to pay more.
	improved durability

Appendix A4.2 – Survey results in Pie-carts, to show response split.

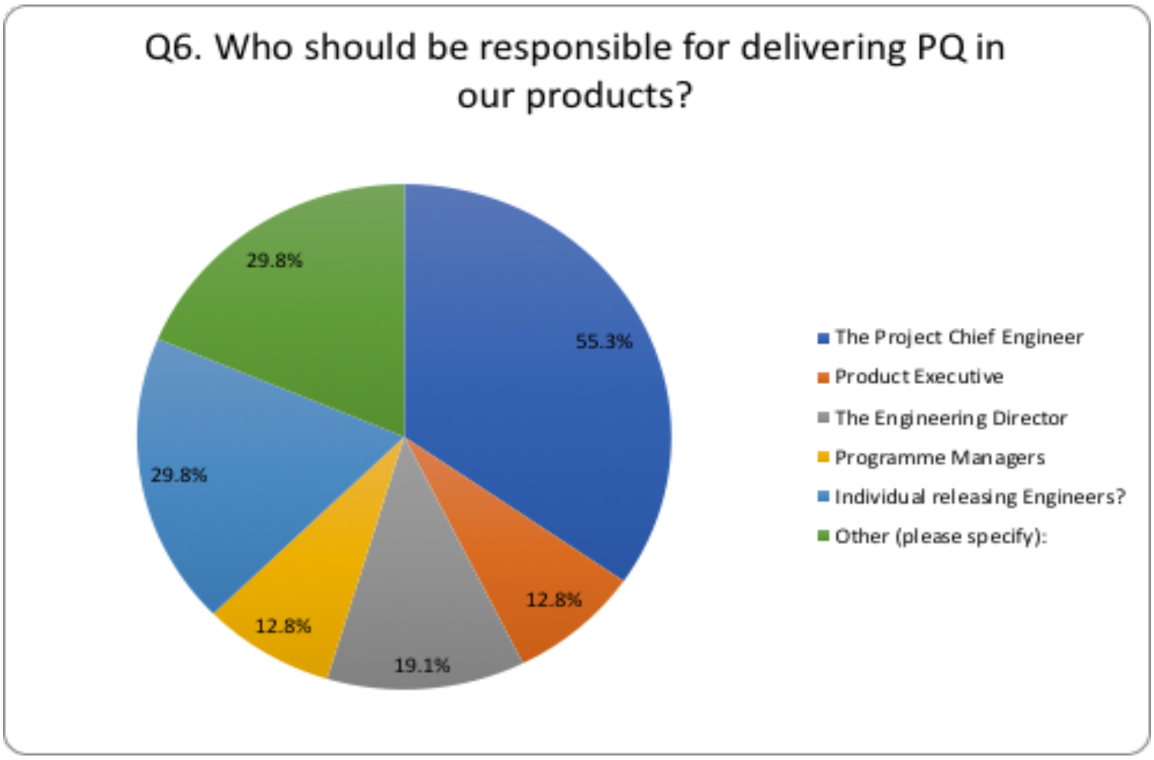


Fig. A4.1. Responses to Question 6 “Who is responsible for PQ in products?”

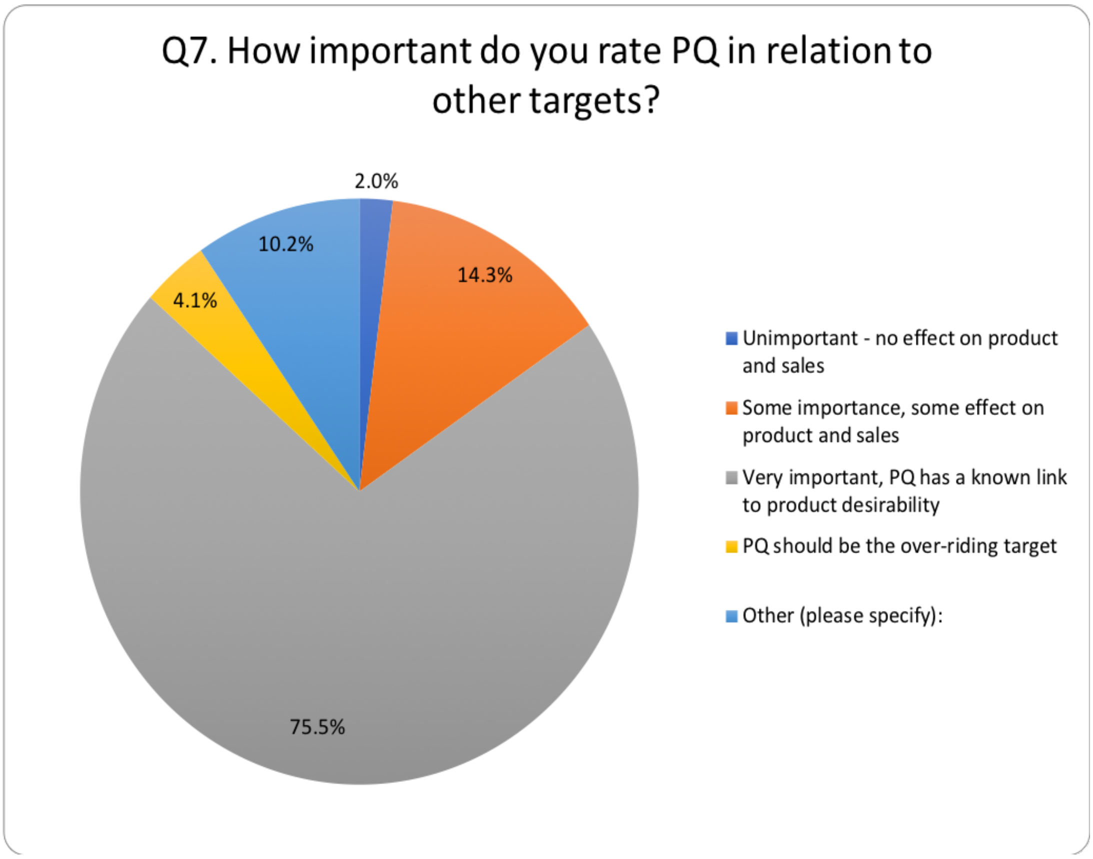


Fig. A 4.2. Question 7 responses about PQ importance.

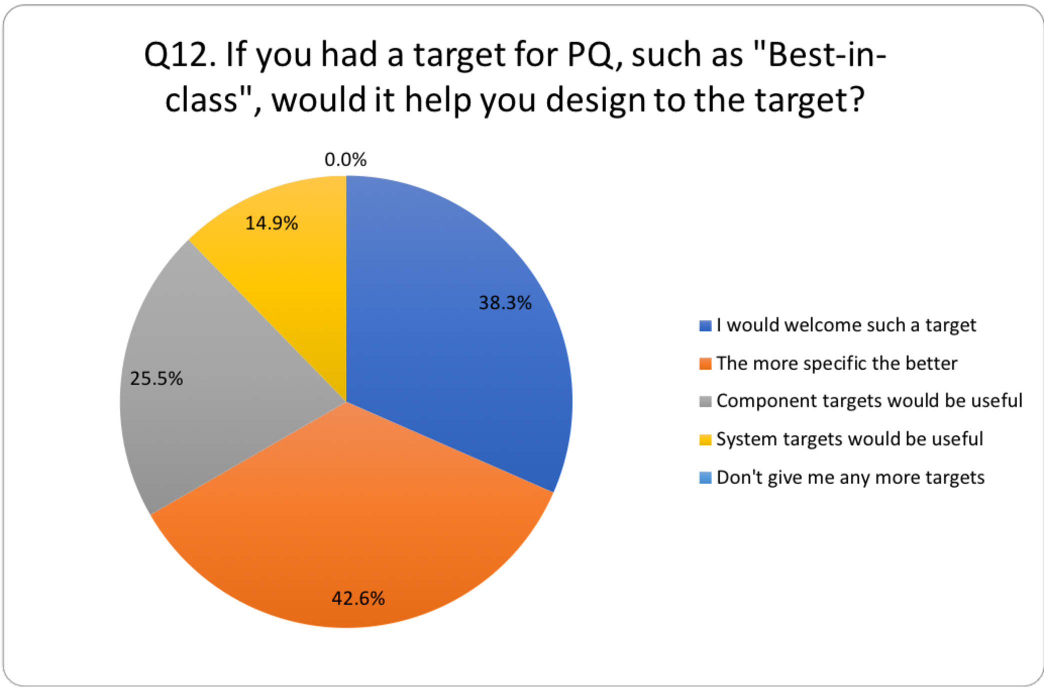


Fig. A4.3. Question 12 results, looking at the use of, or need for PQ targets.

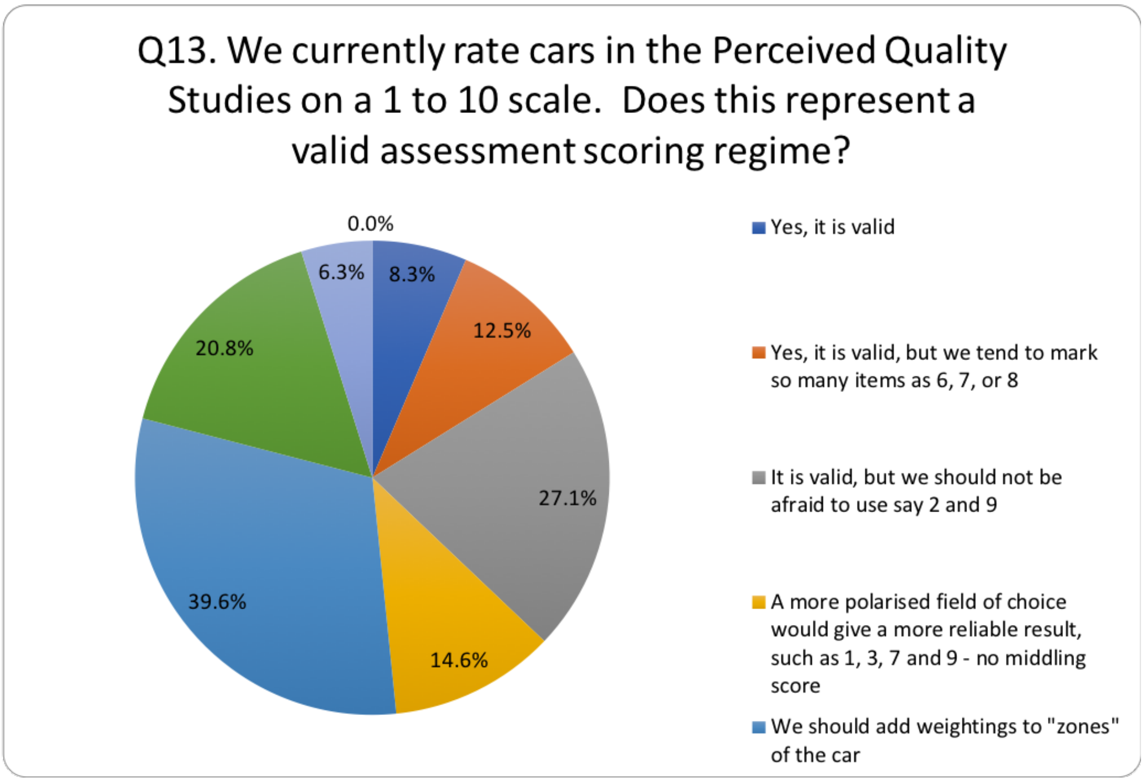


Fig. A4.4. Question 13 results.

Appendix A4.3 Statistical analysis

Q 6 Awareness * Responsibility **Crosstabulation**

Count

		q10V6					
		1	2	3	4	5	Total
q1V3	1	1	21	5	1	2	30
	2	1	9	8	0	1	19
Total		2	30	13	1	3	49

Q 10 Awareness * Benchmark data **Crosstabulation**

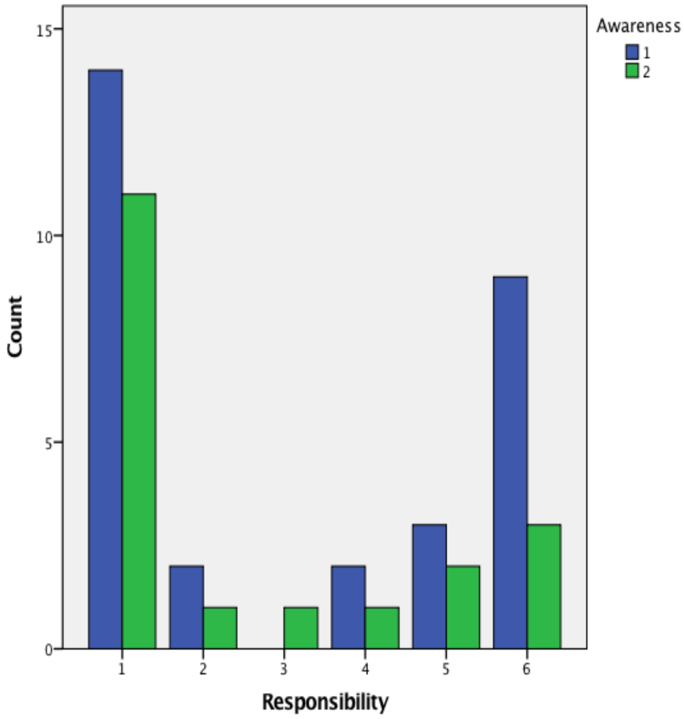
Count

		q6V5						Total
		1	2	3	4	5	6	
q1V3	1	14	2	0	2	3	9	30
	2	11	1	1	1	2	3	19
Total		25	3	1	3	5	12	49

Q 13 Awareness * PQ scale **Crosstabulation**

Count

		q13V7							Total
		1	2	3	4	5	6	7	
q1V3	1	2	4	8	5	5	3	3	30
	2	2	2	6	1	5	2	1	19
Total		4	6	14	6	10	5	4	49

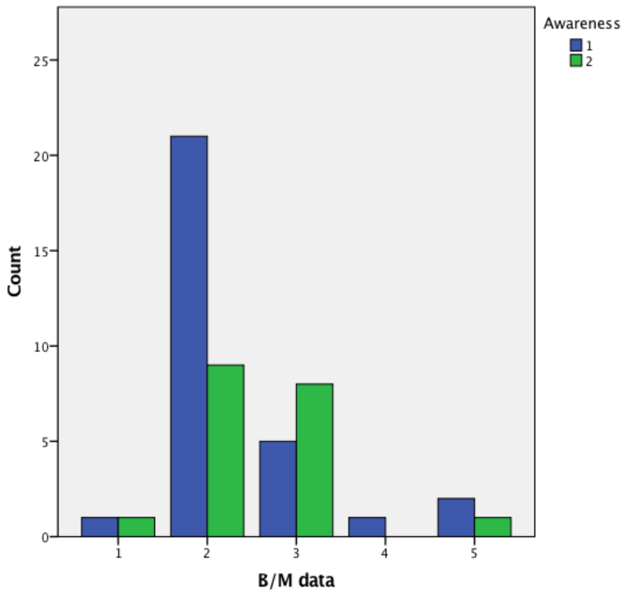


Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	2.904[a]	5	.715
Likelihood Ratio	3.277	5	.657
Linear-by-Linear Association	.980	1	.322
N of Valid Cases	49		

a. 9 cells (75.0%) have expected count less than 5. The minimum expected count is .39.

Test for Awareness versus Responsibility

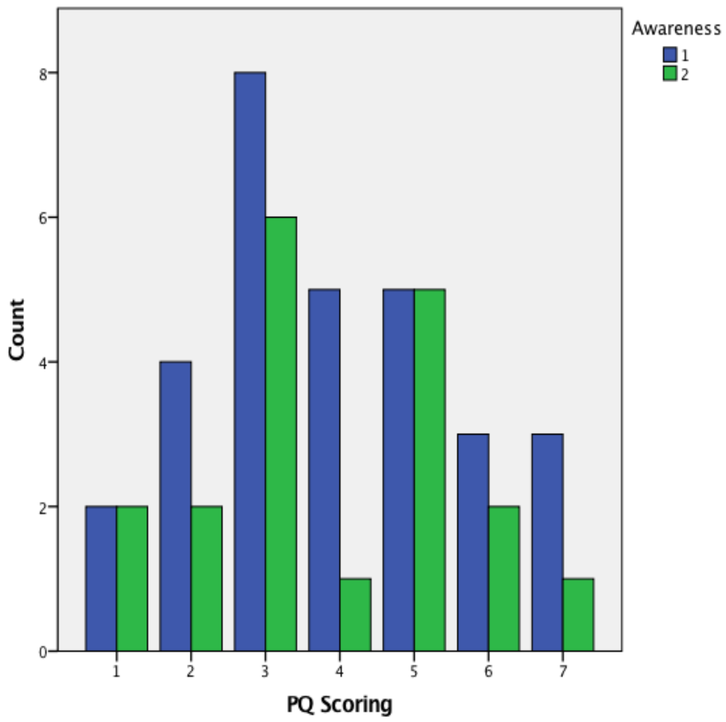


Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	4.587[a]	4	.332
Likelihood Ratio	4.871	4	.301
Linear-by-Linear Association	.247	1	.619
N of Valid Cases	49		

a. 6 cells (60.0%) have expected count less than 5. The minimum expected count is .39.

Test for Awareness versus Benchmarking



Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	2.474[a]	6	.871
Likelihood Ratio	2.635	6	.853
Linear-by-Linear Association	.083	1	.773
N of Valid Cases	49		

a. 11 cells (78.6%) have expected count less than 5. The minimum expected count is 1.55.

Test for Awareness versus current PQ scale

These graphs above show the relationship (or lack thereof) between Awareness, PQ Responsibility, Benchmarking and the current PQ scale.

Appendix A4.4 Mann-Whitney U test assumptions and results

One dependent ordinal variable

1. One independent variable comprised of two independent groups
2. Independent observations
3. Decide upon whether scores are distributed differently or the same.

Ranks

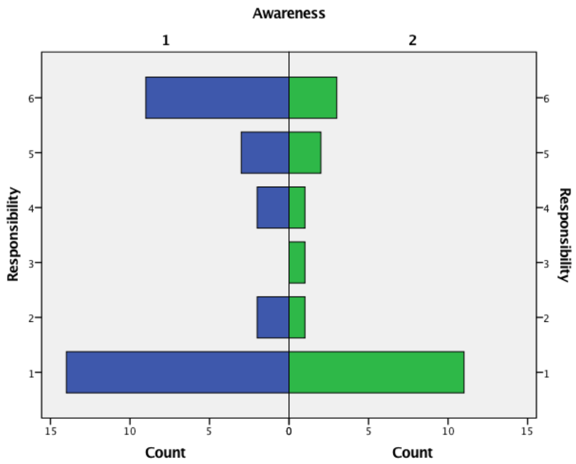
	Awareness	N	Mean Rank	Sum of Ranks
Responsibility	1	30	26.48	794.50
	2	19	22.66	430.50
	Total	49		
B/M data	1	30	23.53	706.00
	2	19	27.32	519.00
	Total	49		
PQ Scoring	1	30	25.38	761.50
	2	19	24.39	463.50
	Total	49		

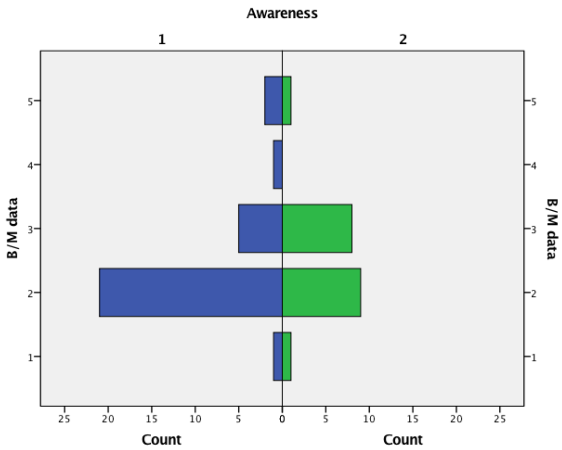
Test Statistics[a]

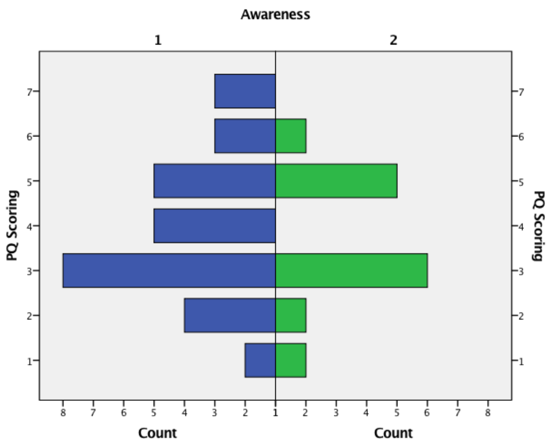
	Responsibility	B/M data	PQ Scoring
Mann-Whitney U	240.500	241.000	273.500
Wilcoxon W	430.500	706.000	463.500
Z	-.990	-1.041	-.240
Asymp. Sig. (2-tailed)	.322	.298	.810

a. Grouping Variable: Awareness

Mann-Whitney Assumption 4 tests for Responsibility, Benchmarking data and PQ Scoring.







All the charts above for the population pyramid test to check Assumption 4, show a similarity of shape between Awareness (or lack thereof) and the three chosen attributes of Responsibility for PQ, Benchmarking of PQ and PQ scoring.

A4.5 Polychoric Factor Analysis results

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Chapter 5 Appendices

A5.1 Review and critique of attributes literature

A5.2 Attribute definitions from the literature

A5.3 Examples of attribute lists from academia, commerce and the media

A5.4 Example of the use of attributes by a not-for-profit organisation.

Appendix A5.1 Review and critique of attributes literature

The summary of research found in 32 papers which mentioned attributes was given in section 1.2 and Fig. 1. The full chart is shown in below. Following this in the Appendix, are details of some of the extant research material which covers the subject of Attributes and the many views given to the subject across the years 1974 to 2017. Each of the papers in the Appendix has been reviewed and critiqued for their attempts to define and measure PQ attributes. This exercise shows how diverse are the attributes investigated and how each relies upon one or more of the senses. Appendix Table 1 shows some of the characteristics covered by the research material.

Attributes section - 32 paper characteristics

Count	Paper no.	Year published	Methodology	User	Mixed	Engin-eering	Subject-ive	Object-ive	Quali-tative	Quanti-tative	Emotion	Senses	Crafts-manship	Culture	Other
				Perspective			Metrics								
1	7	2009	List	X			X		X			X	X	X	Social science aspect
2	15	2012	List	X			X		X		X	X			Customer journey
3	23	1984	Dimensions			X	X		X						Definitions, cost
4	25	2009	Published data review	X				X		X	X			X	Automotive reputation
5	33	2007	Clinics	X			X		X		X	X			Study on Luxury
6	66	2004	Clinics		X			X		X	X	X			Sound only study
7	69	2012	Clinics		X		X		X		X	X			Focused on rotary dials
8	72	1993	Framework	X			X		X		X				Customer journey
9	77	2013	Clinics	X			X		X		X	X			Sound only study
10	81	2009	Clinics	X			X		X			X			Focused on switches
11	87	1997	List		X		X		X			X			Psychology, measures
12	89	1995	Model		X		X		X						Non-automotive customer cues
13	92	2013	Clinics			X	X		X			X			Panel split-lines only
14	98	2006	Long-term data collection	X				X		X					Covered 12 year period.
15	99	2014	Survey	X			X		X		X				
16	109	2009	Model	X			X		X			X	X		Check-list
17	119	2006	Questionnaires	X			X		X					X	Purchase link
18	168	2014	Clinics	X				X	X			X		X	Haptics Thesis
19	179	2016	Product Appraisal	X			X		X		X	X		X	D&E
20	181	2002	Model	X			X		X		X	X			Product and Emotion Navigator proposal
21	209	2016	List	X				X	X	X		X			Attribute listing
22	219	2015	Model			X	X		X		X	X			Used word-tree
23	222	2015	Model			X	X		X			X			Psychology
24	237	2017	Sampling	X			X		X						Purchasing
25	242	2005	Media review	X			X		X		X			X	Data presentation
26	257	2010	Surveys, focus groups, b/m.		X		X		X		X	X	X		Conjoint analysis
27	258	2010	Interviews and obs.	X			X	X	X	X	X	X			Supply chain
28	259	2017	Framework		X		X	X	X			X		X	Fuzzy
29	260	1974	Survey	X			X		X						Non-automotive
30	261	2008	Model		X		X	X	X		X	X			X
31	263	2009	Model		X		X	X	X		X		X		
32	265	2007	Survey		X		X	X	X		X	X	X		Audits
			Column totals	**19**	**9**	**4**	**27**	**10**	**29**	**5**	**17**	**21**	**5**	**7**	
					2										

N.B. Some papers do present both Subjective and Objective data and Qualitative and Quantitative views.

Table A5.1 Assessment of 32 papers concerning attributes

Table A5.1 preceding was created to summarise and show how the various researchers investigated the subject. Table A4.2 below shows the explanation of the columns.

Legend for Table 1 of research papers on attributes	
Legend or column	**Explanation**
Column 1	Order as reviewed in the Critiques Appendix.
Column 2	Identification number in RefWorks.
Date	Year of publication.
Methodology	How the researchers tackled the subject.
Perspective	Whether either or both the User and Engineering were the driver for the research or indeed the customer of the same.
Metrics	What measures were used in the research and could be both Subjective and Objective and Qualitative as well as Quantitative.
Senses	Tally of these mentioned in the material.
Craftsmanship	Tally - recorded if this were a tenet of the work.
Culture	Marked if this was an intentional or unintentional facet, meaning that the work was conducted outside the UK.
Other	Any remaining PQ aspect not covered by the previous columns.

Table A4.2. Results of attributes literature review.

Part of the Research Questions and *raison d'être* for this thesis is the search for a measure of PQ. Emotion was anticipated to be a key component of PQ research and shows itself as a strong link across over half the material. Craftsmanship is a subject discussed at length in many automotive design circles and was hoped to make a strong showing, but as the statistics indicated only 5 papers broached this subject, perhaps there is room for more research in this line.

The final column also shows a statistic that few of these pieces of work on PQ actually generated a list of Attributes.

Appendix A5.2 Attribute definitions from the Literature

Table of attribute definitions or statements from the Literature		
a)	Attributes should be given an Engineering measure or characteristic.	(Ersal et al. 2011).
b)	Engineering attributes should be translated from market research and themselves morph into manufacturing specifications.	(Garvin 1984).
c)	There are idiosyncratic attributes that relate to art, beauty and social interaction.	(Golder, Mitra and Moorman 2012).
d)	The subjective nature of attributes and little data showing their importance to the customer make it difficult to assess in early D&D. There is still no clear path on which PQ attributes to concentrate upon and when in product development.	(Stylidis, Wickman and Söderberg 2015).
e)	There is little agreement on what are the vital product attributes and their comparative significance. No magazine or website attribute listing agrees with any other in terms of what is important.	(Kukova 2016).
f)	There is not always a straight cause and effect relationship; the product itself may not cause a reaction, but an elucidation based on its attributes.	(Desmet and Hekkert 2002).
g)	All attributes, including product quality had a positive relationship with purchase intention.	(Tsiotsou 2006).
h)	There are four clusters of perceived attributes: Auditory, Quality, Driving comfort and Usability.	(Hossoy et al. 2004).
i)	There is still “no overall systematic in detail” and customers cannot articulate what they want, but OEMs can gather attribute information.	(Lieb, Quattelbaum and Schmitt 2008)
j)	44 attributes whittled down to 26, of which 10 were significant (but even these over-lapped).	(Schmitt, Quattelbaum and Falk 2010)
k)	Attributes can number between 40 and 120, depending upon size of the organisation. PQ can be different at different OEMs, although each one will wish to create a case that creates the best perception by the customer.	(Schmitt, Quattelbaum and Falk 2010).

Table. A5.3. Examples of attribute lists from academia, commerce and the media

Appendix A5.3 Examples of attribute lists from academia, commerce and the media

Table 1 List of perceived attributes of vehicle interiors (assessment of craftsmanship)

No.	*Name*
f_1	Ability to easily discern where all controls are located
f_2	Hollow resonance
f_3	Component feel/sound of activation/engagement (Seatbelts, doors, buttons)
f_4	Buzz, Squeak, and Rattle (BSR)
f_5	Stitching quality
f_6	Adjustability of components
f_7	Shape harmony
f_8	Colour harmony
f_9	Storage space in front console
f_{10}	Visibility of mechanical elements and manufacturing distortions
f_{11}	Component/passenger interference
f_{12}	Material quality
f_{13}	Seated comfort
f_{14}	Difficulty reaching controls, lights and seatbelts
f_{15}	Consistency of tactile feel
f_{16}	Usability of vents
f_{17}	Usability of glove box
f_{18}	Usability of door pockets
f_{19}	Usability of sun visors
f_{20}	Usability of cup holders
f_{21}	Usability of trunk
f_{22}	Quality of finishing

Table A5.4. Craftsmanship attributes from academia (Petiot et al. 2009).

Table 5
Factor topics.

Factor	Factor topic
1	Lack of reliability and safety
2	Personal identification
3	Comfort (due to lack of sensorial displeasure)
4	Fragility
5	Ease for use
6	Social power
7	Maintenance costs
8	Fuel costs
9	Taxes and insurance costs
10	Inferiority to other cars
11	Predictability in use
12	Reselling potential
13	Lack of value for money
14	Problems caused by the driver
15	Visual breadth

Table A5.5. Factors from academia. (Tonetto and Desmet 2016).

Table A5.6. JD Power categories

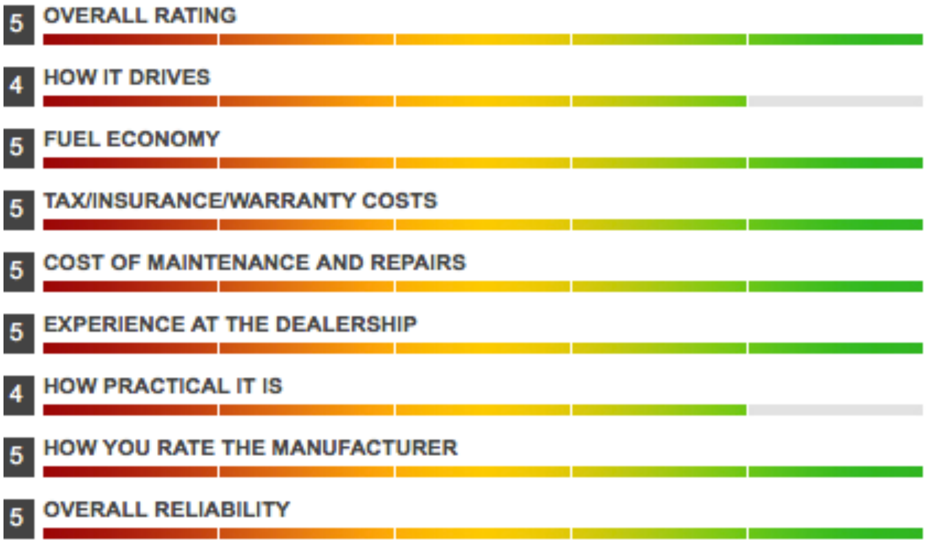

Table A5.7. Honest John attributes from Daily Telegraph Motoring newspaper (HonestJohn 2018)

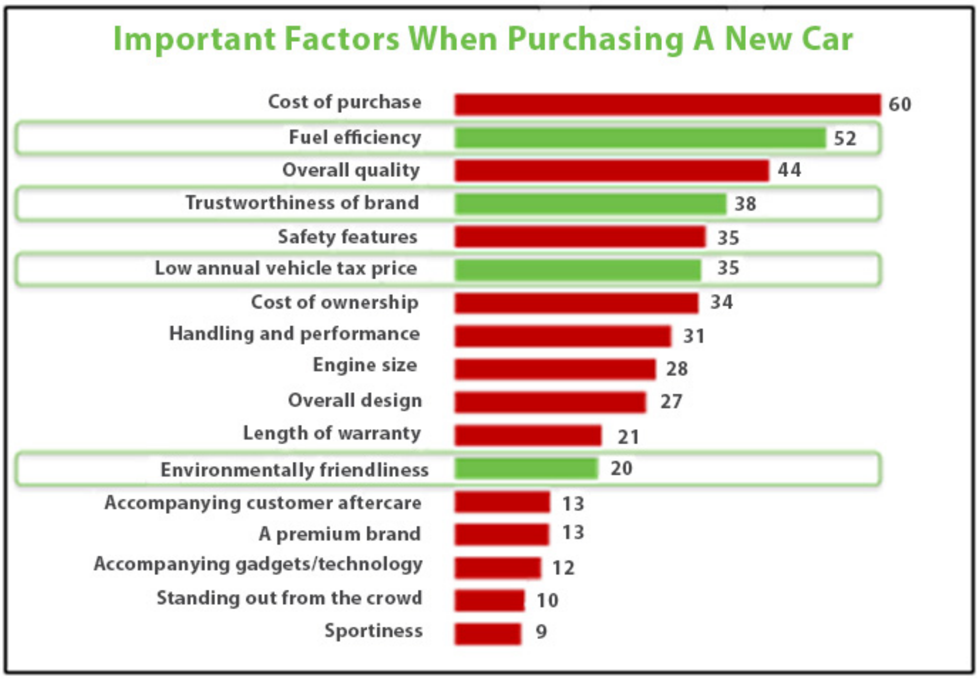

Table A5.8. Harris interactive (Pickering 2012).

Analysis of four attribute lists – two academic and two commercial				
No.	**Tonetto and Desmet – Ergonomics Academic**	**Petiot et al. 2009 – Craftsmanship Academic**	**Harris Interactive - Commercial**	**The Honest John Column' - Commercial**
1	Lack of reliability and safety	Ability to discern where all controls are located	Cost of purchase	Overall rating
2	Personal identification	Hollow resonance	Fuel efficiency	How it drives
3	Comfort (due to lack of sensorial displeasure)	Component feel/sound of activation	Overall Quality	Tax/Insurance/Warranty costs
4	Fragility	BSR	Trustworthiness of brand	Cost of maintenance and repairs
5	Ease of use	Stitching quality	Safety features	Experience at the dealership
6	Social power	Adjustability of components	Low annual vehicle tax price	How practical it is
7	Maintenance costs	Shape harmony	Cost of ownership	How you rate the manufacturer
8	Fuel costs	Colour harmony	Handling and performance	Overall reliability
9	Tax and insurance costs	Storage space in front console	Engine size	
10	Inferiority to other cars	Visibility of mechanical elements and manufacturing distortion.	Overall design	
11	Predictability in use	Component/passenger interference	Length of Warranty	
12	Reselling potential	Material quality	Environmental friendliness	
13	Lack of value for money	Seated comfort	After care	
14	Problems caused by the driver	Difficulty reaching controls, lights and seatbelts	A premium brand	
15	Visual breadth	Consistency of tactile feel.	Accompanying gadgets/tech	
16		Usability of vents	Standing out from	

			the crowd	
17		Usability of glove pockets	Sportiness	
18		Usability of door pockets		
19		Usability of sun-visors		
21		Usability of cup-holders		
22		Usability of trunk		
23		Quality of finishing		

Table A5.9. Comparison of two academic and two commercial lists.

As can be seen, there is little or no agreement on what the important factors are in the commercial or academic world. There is little strict word-for-word commonality across the four columns. However, it could be argued that there is high commonality as some of the attributes could be taken to mean the same things, such as “Ease of use from column 1 could be a paraphrase of “Ability to discern where all controls are located” form the next column. Column 1 attribute “Comfort (due to lack of sensorial displeasure) could be paraphrased by “Seated comfort” in column 2.

The word quality does not appear in the first column, yet costs do. Quality appears three times in column 2, costs do not, yet practicality issues do. Costs occur three times in column 3, yet to consider the BMW example, ‘sportiness’ (whatever that means), could be a BMW brand attribute is mentioned. The last example, with the shortest list of attributes, mentions “How it drives’, which again could be a BMW attribute and is implied by their tag-line in Fig. 1.

Appendix A5.4 Example of the use of Attributes by a not-for-profit organisation.

The following was written by the creator and co-ordinator of a world-wide not-for-profit assessment of motor vehicles but voted upon solely by women. The COTY (Car of The Year) Awards have been running for many years but featured very few women on the voting panel and so the writer of the piece following decided to create her own award but voted upon by women.

Women's World
Car of the Year

7th February 2018

MEMO: **Ian Pogson**

RE: **Outline of judging criteria**

From the very beginning of Women's World Car of the Year (2009) when we had only eight judges on the panel, it was decided we should vote according to how women buy cars.

We now have 28 judges on the panel and that has never changed. Our method of judging has changed over the years, however, but mainly to streamline procedures.

We do not have a committee that decides what cars make the short-list. In a very democratic process our judges submit their top five preferences in six categories. In 2017, 420 cars were nominated. This list is whittled down and the most-suggested cars naturally make the short-list.

Judges then vote on five nominated cars in each category, so 30 cars in total. When the winners in each category are known, judges vote again for the supreme winner.

Broadly speaking, our judging criteria is (and not necessarily in order):

- Driveability – we don't place a strong emphasis on Newton metres of torque or power-to-weight ratios.
- Storage
- Design
- Value for money
- Fuel economy
- Safety
- Sex appeal

We have one more category. It's the Holly Reich Dream Car award – named for one of our judges from New York who passed away 18 months ago. This is one nomination only – it's the car you'd love to own if you had the opportunity.
In 2017 the car that won the award was the McLaren 570S and it's interesting to note that McLaren cars have said they are going to gear their marketing more to women than they have in the past.

OTHER COMMENTS:
In 2016 Mr Haakan Samuelsson, CEO of Volvo Group, told us there are only three car awards in the world that Volvo recognise – and Women's World Car of the Year is one of them.
In 2017 Dr Ralph Speth, CEO of Jaguar Land Rover told us that during the next decade car companies will 'wake up' and start to consider women in their advertising and marketing. He told us to keep going! Never to give up what we are doing with Women's World Car of the Year.
There is no doubt, however, that the very fact Women's World Car of the Year exists, seems to cause some problems with some people. We have been told it's 'sexist', that there should be a 'men's award', and that we are 'elitist'. We simply do not see that.
The reason we started was that in 2008 there were 45 judges on the World Car of the Year. Not one was a woman. That's now changed although of the 81 judges they currently have on their panel, only four are women.
We are not in competition with any other car awards in the world. We see ourselves as representing a voice for women in motoring. That is our entire *raison d'etre.* We hope that what we do is representative of women car customers. If that advises the car industry and the advertising industry, it's a bonus.

SANDY MYHRE, CEO, WOMEN'S WORLD CAR OF THE YEAR
NEW ZEALAND.

A5.5 Furniture manufacturer visit report

Visit Report – Iain James Furniture 30th May 2014

Ian Pogson - Coventry University
Iain Mitchell – M.D. Iain James Furniture.

Aim of visit – to discuss the attitude of Iain James Furniture to PQ (Perceived Quality).

Time courteously given - 90 minutes.

Brief background to Company

From their excellent brochure, "Iain James Furniture is the younger of two established family owned furniture businesses owned and managed by the Mitchell family." The other is Artistic Upholstery. Both are based in a part of the UK renowned for its furniture making skills: Long Eaton, Derbyshire.
Iain Mitchell is the M.D. of Iain James and also takes on the mantle of Principal Designer and being a small company, very many other roles.
The product is top quality reproduction furniture in antique or Art Deco styles, using ebony, maple, Japanese ash, walnut, mahogany, oak, poplar, yew and other veneer finishes. They are a founder member of Woodland Heritage, an organisation dedicated to the long-term sustainment of British woodlands and forests.

The Interview

Perceived Quality was evident from the moment one passed through the green on-street "Reception" door, which led into a carpeted lobby with Georgian-style doors and windows, allowing a peek into the large showroom.

Design and PQ are closely related, as is evident with such a product as furniture. The interview was conducted on a beautifully upholstered sofa, surrounded by occasional furniture, dining tables and chairs, bookcases and cabinets in a wealth of styles and finishes.

Iain was careful to introduce the subject of design, for in a small company such as his the process is far less regimented than the automotive industry and seems to take place in an ad-hoc fashion by conversation about style, finish and with very little CAD or formal draughting. Iain will discuss future plans with experienced colleagues to keep up with market trends or set new ones. One such new trend was strikingly demonstrated by a round Art Deco style table on a simple hexagonal tapered plinth supported by a curved "triangular" block base and veneered with very bright, heavily textured Japanese ash and two concentric rings. The effect was stunning and a tactile delight.

History and practicality met in many pieces in the showroom; Iain was again at pains to point out that some straight copies of antiques were out of keeping with current fashion and could be viewed as too fussy, with excess detail (and therefore expense) on table legs for instance, when the accent of the piece was on the table top surface. He is very aware of making the piece appeal visually, yet be practical.

New product needed to be "welcoming; to make an individual statement" and form an "accent piece". Many of the items on show did just that.

Much of the PQ appeal for such product lies in the finish, the polishing process, where Iain James Furniture has been fortunate in retaining the skills of an otherwise disappearing group of polishers. Also in decline has been the cabinetmakers themselves, which used to be concentrated in the East End of London and are now to be found elsewhere around the UK, such as Norfolk ***and Essex.***

The finishing process involves stripping much of the natural colour of the veneers with a special two-part bleach and then after drying adding some artificial stain to achieve a base colour ***which is then sealed with French polish or lacquer prior to be being distressed and antiqued by creating small scratches and splashes in the finish. A 'stipple' is then applied to all the surface and carefully removed which enhances the antiqued areas and highlights the important shaded areas created by this application. Many additional layers of polish are then applied between sanding before the desired patina is achieved. The final processes include careful dulling of the finish by the use of pumice-stones powder, fine wire wool before waxing with a high quality beeswax.***

These labour intensive procedures take five working days to achieve the tactility-pleasing rich hues and swirls of the finished piece. Imperfections are retained in the veneer to add authenticity and highlights to the finished surface.

Veneers are very much the personal choice of the Designer; with anticipation that when stripped, stained and polished, the customer will be enticed to buy.
Consumers are able to purchase the product through high quality retailers or Interior Designers.
The veneer, with some patina and slight distressing is skilfully applied to suit particular styles and personal choices with efforts made to ensure that when several pieces are ordered that they match, within the realms of what is possible when dealing with real wood finishes.

Iain expressed an opinion on automotive interior detailing, that he appreciates those manufacturers who employ a real veneer and create a richness and depth to an interior finish. He kindly furnished the writer with a sample piece of walnut veneer with satin cross-banding. Perhaps this could be considered for Roewe branded vehicles.

Summary

A thoroughly worthwhile visit, entertained with great passion and courtesy. The closeness of PQ and Design was clear to see, as was the directness of both of these elements to the Customer.
There is much to learn about craftsmanship, jointing, tactility and finish from such an industry.

Ian Pogson May 2014

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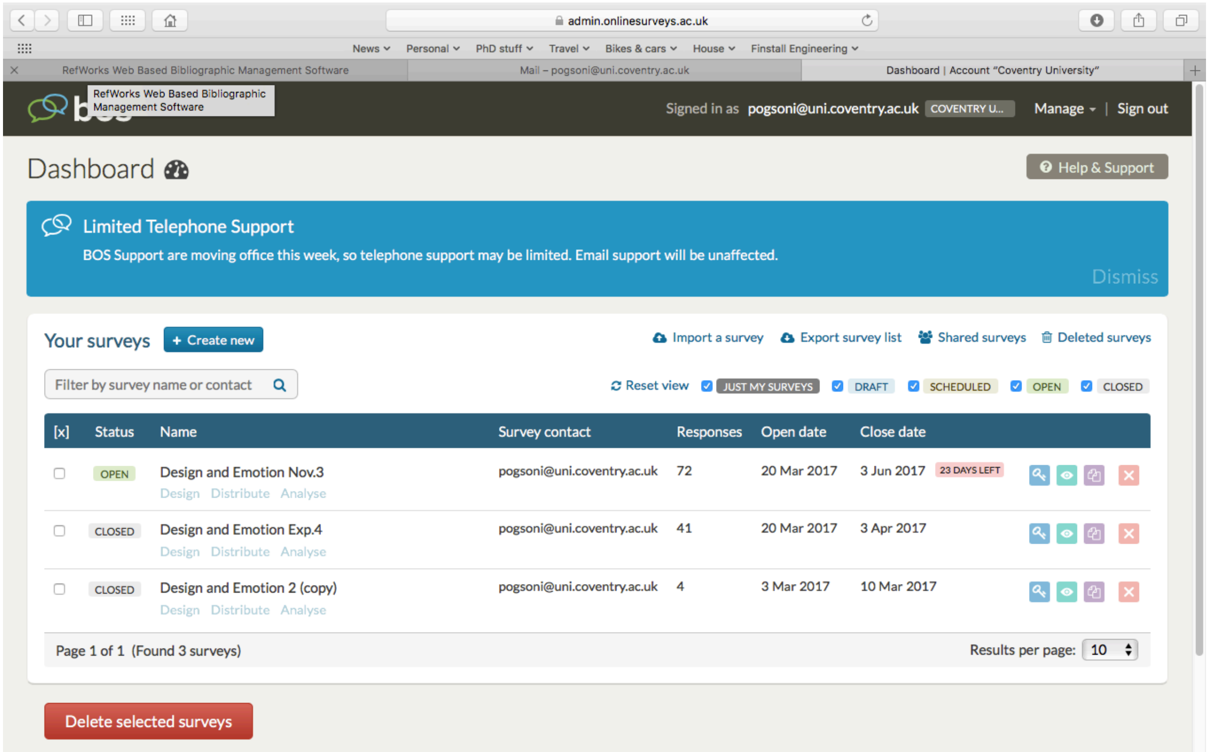
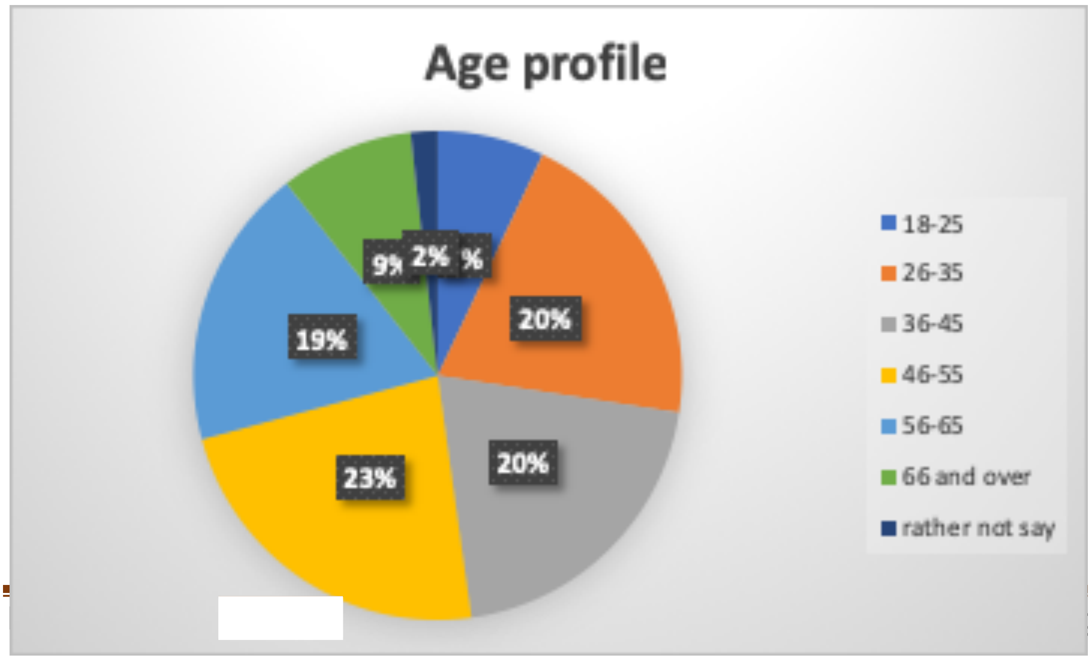
(Note, the bold italic text was added by the interviwee, as a courtesy).

Chapter 6 Appendices

Appendix A6.1. The split of the surveys (the pilot, novices and experts)



Appendix A6.2. Age profile of respondents



Appendix A6.3. Sample response from pilot survey in Excel

(Fokkinga *et al.* 2014).

DESIGN AND EMOTION			
(Fokkinga et al. 2015)			
OVERALL EFFECT	QUALITY of LIFE and SOCIETY		
	Should a scooter look THIS pretty? So; eye candy, frugal, *light,* automatic, stop-go technology(!) and an eye-opener.		
	BEHAVIOUR (Doing) [Does it make one do anything different?]	EXPERIENCE (Feeling) [Functional and affective)	ATTITUDE (Seeing) [Any new view of self or others through use of product]
	I would actually take the bike out on wet, dirty roads and enjoy it because I know I won't have to spend ages cleaning it when I get back!	Instils a feeling of confidence i.e. I feel I am in control of it rather than than the opposite when on a bigger bike.	Affirming and reassuring that riders of big bikes still give an acknowledging nod of the head to the tiddlers on the road (I always do when on my own 'big' bike)
INTERACTION	AESTHETICS	EMOTIONS (Evoked by product)	PRODUCT MEANING (Descriptors)
	Those gorgeous looks.	Confirms my belief that less is more.	Admiration, satisfaction, pleasure.
	HUMAN-PRODUCT INTERACTION (What one does with product)	A good value, unpretentious, dependable bike that continues to impress by its deliverance of everything its specification promises.	
	PRODUCT PROPERTIES (Spec.)	Guess what - those looks! Add the convenience and sheer usability and you have the perfect commuter. So all is perfect then? Not quite. Ergonomics not *quite* right for me and I find myself constantly adjusting my riding position for comfort, but hey, a 95 mile run on it with no serious aches or pains can't be bad, can it?	

Appendix A6.4. Questions from survey as shown in a completed example.

Design And Emotion

Page 1: Introduction

Q1. Your age
18-24

Q2. Your Gender
Female

Q3. Your educational background - tick all that apply
Degree

Q4. Your cultural background - this is important as it will affect your view
White British

Q5. Your interest in things automotive
I drive for pleasure

Page 2: Main Survey

Q6. Please give a brief description of the make and model of bike, van or car, e.g. BMW 3-series saloon, then say is it your own choice or foisted upon you?

Make and model	Fiat 500
Type of vehicle (e.g. sports car or trail bike).	City Car
Any other details you fancy adding, such as engine	-
It is my choice	-
It is not my choice	Not my choice, bit girly for my tastes, but its shared with my mom!

Q7. What do you primarily use the vehicle for? Put Y or yes against all that apply.

Business	-
Pleasure	Y
Commuting	-
Other	-

Q8. In terms of the vehicle's aesthetics, do you like the design, shape, colour, or is it just a mode of transport? In other words, do you sometimes walk away and look back at it?

I do like the fact that it comes in a range of colours and the interior and exterior are very customizable. It's a fun looking car and I always notice other Fiat 500s when I'm driving

Q9. What emotions are stirred up by using this vehicle? For example - Joy, disgust, no emotion at all……..

Joy, but also slight embarassment? It feels a little cliche to drive.

Q10. What meaning does the vehicle have to you? i.e. what nouns or adjectives would you use to describe it?

Freedom, Fun, Adventure

Q11. Does the product stimulate, influence or facilitate any new or different behaviour due to use? For example - Do you ride or drive it for occasional pleasure? Does it make you drive quickly or slowly? Do you cruise around looking at your reflection in shop windows?

I definitely drive it a lot slower than I did the car I learnt to drive in, I tend to be very cautious in this car. Sometimes I like to just take it out to drive for fun instead of having an actualy destination

Q12. In terms of your experience of it, what emotions does use of the product evoke? What does it make possible? For example - Do you feel proud to own it or are you not bothered?
A little embarassed, but overall I enjoy having it as a practicality.

Q13. Penultimate question - In terms of your attitude to it, or the way you see the vehicle, does the product help perceive, realise or appreciate something? For example - Is it something you always wanted to own or are you saddled with it due to work or family commitments?
I'm more just saddled with it, because I've not yet been able to afford my own car. That's definitely the dream.

Q14. Last one - in terms of quality of life and Society at large, does the product contribute to pleasure, personal significance and virtue? Or again, is it a necessary evil? Have you a 'green' vehicle to try and do your bit for the planet?
I think its very low in emissions, which is something I would take into consider when I by my own car.

Appendix A6.5. Further sample verbatims

Additional comments to those shown in the Results section 4.0 are listed below for Question 11, which enquires of the respondent their attitude to the vehicle.

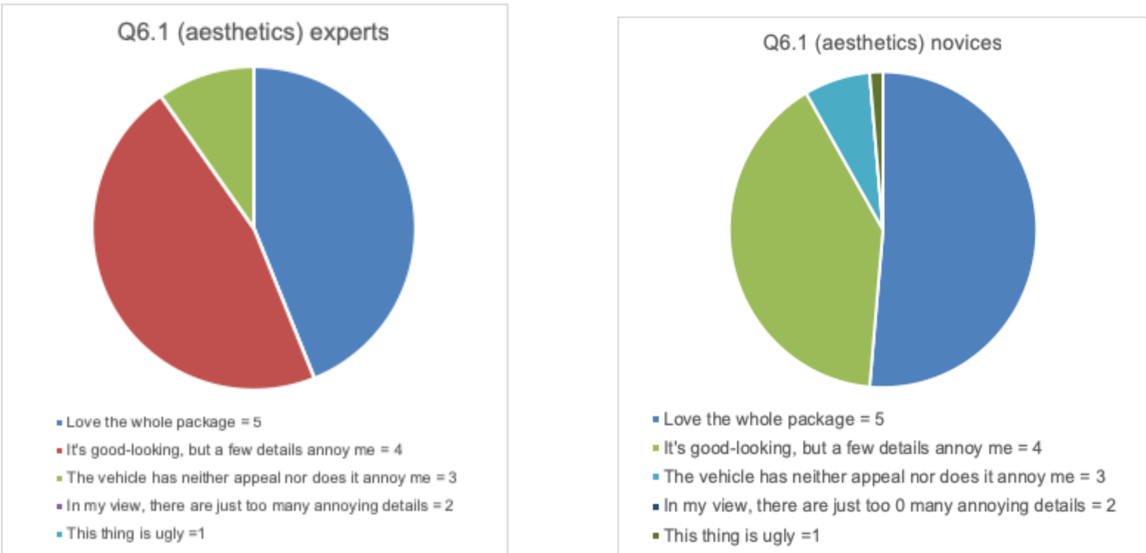
6. "The car has helped me appreciate the VFM it represents: - a more expensive car isn't going to do anything more for me than this one does really."
7. "I think the vehicle makes me look for better quality in a car, more expensive looking features."
8. "Arrival in style!"
9. "The journey is fun and it's not just the arriving that matters."
10. "'Quality' brands unnecessarily expensive and often filled with features that are rarely, if ever, understood or used to the full by their owners."
11. "If I have to have a second car it would be an AMG C class coupe or M4 BMW, a Volvo is a compromise but a necessary one."
12. "I love Jaguars and was always going to have an XE. I want an F-type SVR but cannot afford one."
13. "Saddled with it due to family commitments."

Extra responses from Question 12 looking for some relationship with the rest of the world in the respondent's use of the vehicle are below:

6. "It is necessary NOT an evil." (A play on the question's words).
7. "It is neither green nor a trophy car. But it makes me feel content."
8. "If I could have got a 4.6L I would have been even happier. Ain't (*sic.*) no replacement for displacement !!!"
9. Contributes to pleasure and companionship."
10. "I have left my stressful job so now am looking to sell the car as it as I no longer need it to feel free."
11. "Ultimately it gets me from A to B. However, it is an enjoyable journey with lots of additional features that make it so."
12. "No, I just love the car - it's not green or economical or sensible it's just an amazing drive."
13. "I'd be just as happy getting places by Star Trek transporter beam."

Appendix A6.6. Comparison of Experts and Novice responses.

Some sample charts are shown below to illustrate that the two groups identified in the survey gave similar results so were combined. For example, the responses to Question 6.1 on aesthetics are shown below.



Appendix Fig. A6.1. Sample responses to Q 6.1 from experts and novices

A similar picture for responses to Question 6c1 is shown below for experts and novices.

Appendix Fig. A6.2. Sample responses to Q 6c1 from experts and novic

Appendix A6.7. Data Analysis for Chapter 5 response

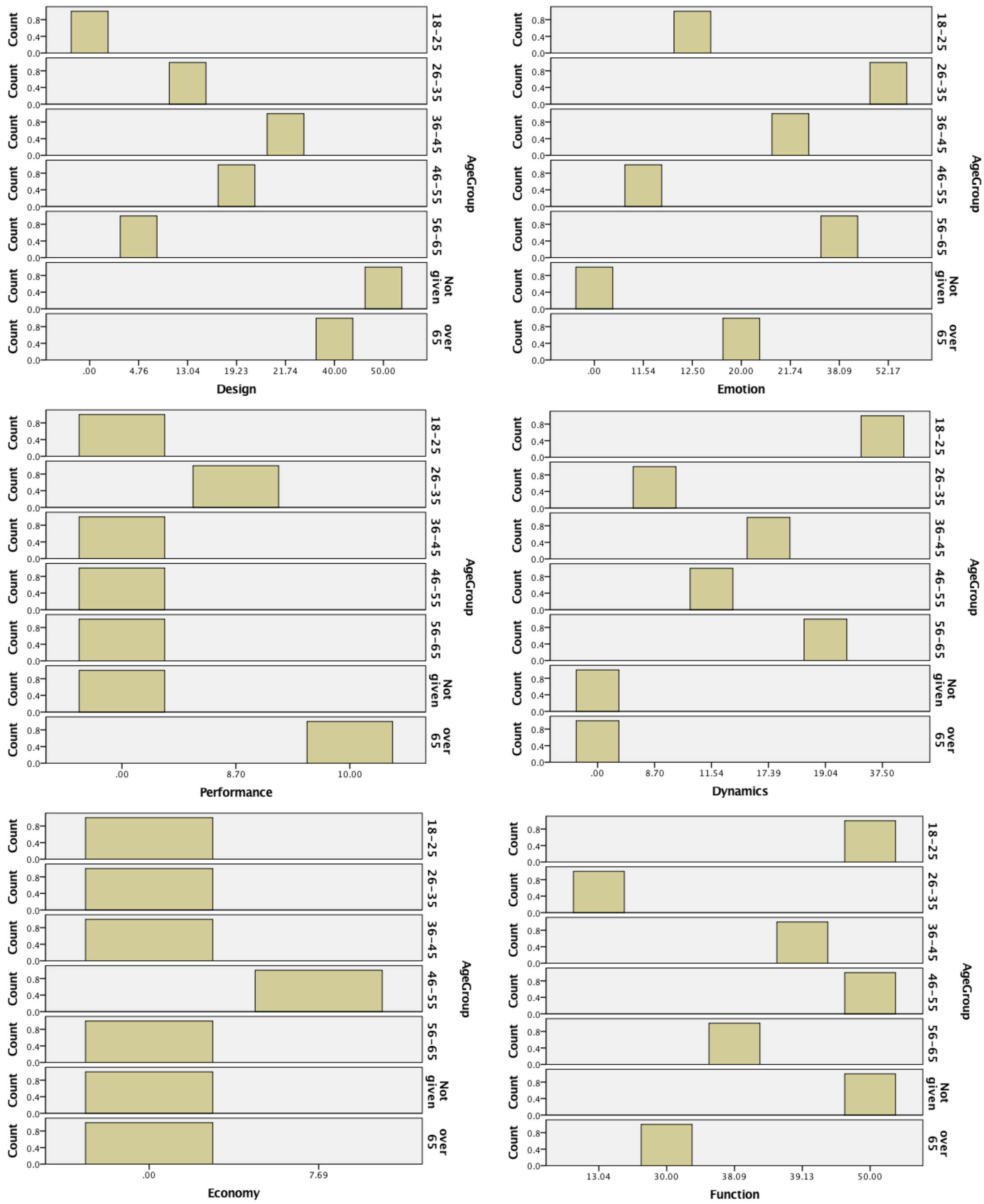
Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	28.000[a]	24	.260
Likelihood Ratio	21.698	24	.597
N of Valid Cases	7		

a. 35 cells (100.0%) have expected count less than 5. The minimum expected count is .14.

Appendix Fig. A5.3 Chi-squared tests

Appendix Fig. A6.4 *below* takes the same base data as shown in Fig.8 but adds in a correction for the numbers of participants within each age range. From the scales of the six graphs it can be seen that they differ, depending upon the frequency of the words used.



Appendix Fig. A6.4. Age range with count overlaid, against six factors.

Test Statistics[a,b]

	QoL_data	Attitude_data	Emotion2_data	Behaviour_data	Adjective_data	Emotion1_data
Kruskal-Wallis H	9.396	12.167	20.745	15.769	18.035	26.323
df	2	2	2	2	2	2
Asymp. Sig.	.009	.002	.000	.000	.000	.000

a. Kruskal Wallis Test

b. Grouping Variable: Aesthetics

Test Statistics[a,b]

	QoL_data	Attitude_data	Emotion2_data	Behaviour_data	Adjective_data	Emotion1_data
Kruskal-Wallis H	28.971	8.094	47.233	12.026	34.341	108.000
df	2	2	2	2	2	2
Asymp. Sig.	.000	.017	.000	.002	.000	.000

a. Kruskal Wallis Test

b. Grouping Variable: Emotion

Test Statistics[a,b]

	QoL_data	Attitude_data	Emotion2_data	Behaviour_data	Adjective_data	Emotion1_data
Kruskal-Wallis H	7.767	5.574	12.374	13.204	13.382	32.311
df	2	2	2	2	2	2
Asymp. Sig.	.021	.062	.002	.001	.001	.000

a. Kruskal Wallis Test

b. Grouping Variable: Ergonomics

Test Statistics[a,b]

	QoL_data	Attitude_data	Emotion2_data	Behaviour_data	Adjective_data	Emotion1_data
Kruskal-Wallis H	2.083	1.306	12.226	3.748	4.958	4.034
df	2	2	2	2	2	2
Asymp. Sig.	.353	.521	.002	.154	.084	.133

a. Kruskal Wallis Test

b. Grouping Variable: Colour

Test Statistics[a,b]

	QoL_data	Attitude_data	Emotion2_data	Behaviour_data	Adjective_data	Emotion1_data
Kruskal-Wallis H	.683	.003	.001	1.554	.105	6.260
df	1	1	1	1	1	1
Asymp. Sig.	.409	.958	.973	.212	.746	.012

a. Kruskal Wallis Test

b. Grouping Variable: Pet_Head

Test Statistics[a,b]

	QoL_data	Attitude_data	Emotion2_data	Behaviour_data	Adjective_data	Emotion1_data
Kruskal-Wallis H	5.178	.832	1.174	1.077	7.601	.740
df	2	2	2	2	2	2
Asymp. Sig.	.075	.660	.556	.584	.022	.691

a. Kruskal Wallis Test

b. Grouping Variable: Education

Test Statistics[a,b]

	QoL_data	Attitude_data	Emotion2_data	Behaviour_data	Adjective_data	Emotion1_data
Kruskal-Wallis H	7.795	12.682	7.877	5.811	2.090	1.400
df	6	6	6	6	6	6
Asymp. Sig.	.254	.048	.247	.445	.911	.966

a. Kruskal Wallis Test

b. Grouping Variable: Age Range

Appendix A6.8 Coding and responses sample page 1

Q6_a	Q6_b	Q6_c	Q7	Q7_a	Q8	Q8_a	Q9
360Bhp, 495Nm & 4 wheel drive.	1	1	1	I would not use this car for my daily commute	Arresting	It really holds	It demands y
package	1	1	1		relaxed	Although it is	I drive in a sn
Its sexy and almost feline	1	1	1		sexy	Because it's	Yes, I drive it
external looks great not ideal entry/exit ergonomics	1	2	2		attractive	it is a mixture	relaxed
Proportion	1	1	1	Great providing no problems	Demanding	The bike is 'a	Given us new
Like me its small and perfectly formed!	1	1	1	It smells like a car not a form of transport.	Fun	It's noisy, rat	Rather than
	1	1	1		Complete	It is for me th	No
Its a bit too square at the back in profile.	3	1	1	I'm not very moody!	Convivial	It just does e	I sometimes

Appendix A6.9 Coding and responses sample page 2

Q6_a	Q6_b	Q6_c	Q7	Q7_a	Q8	Q8_a	Q9
all the extras I'd never be able to afford on a newer car - satnav, leather upholstery, air con, automatic mirrors/lights/windscreen wipers - lots of toys!	1	1	1	it is a very easy car to drive and goes fast and makes a lot of noise	mine	I think we're	extremely cc
Quality of finish	1	1	2	Feels rough/ hard work when tired	Exhilarating	It handles su	Relaxation
no	1	1	2		my car is trou	because it gi	yes - it make
engine harsh on pull away / accel	1	1	3		Spacious	Very importa	No
3.9L V8 engine	3	2	1	This motor makes me smile.	Capable	Its the best n	I do not rush
space, driving position, roominess, brand value, economy, might not be the best looking or have a particularly great interior experience but it ticks many boxes for me/us	1	1	1		comfortable	My 3rd vehic	slow smooth
Sport design	2	2	1	Good smooth ride but can be aggressive if required	Powerful	Lots of powe	Drive more r
	1	1	1	The acceleration and looks make me smile.	Sleek	An E92 is, in	It makes me

The sample screenshots above show the coding applied to the responses for those questions for which it was appropriate (e.g. a Likert scale response).

Chapter 7 Appendices

Appendix 7.1 Validation Declarations

AJ Hall signed validation
S Owen signed validation

These are scanned copies from the interviews.

Content removed on data protection grounds

Content removed on data protection grounds

Content removed on data protection grounds

Glossary of terms

I S Pogson PhD Thesis Glossary of Terms		
A		
	AHP	Analytic Hierarchical Process, used to compare different groups (of people, attributes, etc.)
	APQP	Advanced Product Quality Planning, similar to Six Sigma, is a framework of procedures and techniques used to develop products particularly in the automotive industry.
	Auditor	A trained Engineer who assesses vehicles for conformance to quality standards
	ASQ	American Society for Quality
B	BS5750	A British Standard for quality - In 1971, the British Standards Institute (BSI) published the first UK standard for quality assurance (BS 9000), which was developed for the electronics industry. ... The purpose of BS5750 was to provide a common contractual document, demonstrating that industrial production was controlled.
C	COC	Centre of (Engineering) Comptetence
	CAS	Computer Aided Styling - a tool, drawing direct to a digital database
D	D&D	Design and Development
E	EFQM	European Foundation for Quality Management
F	FRM	Final Reachability Matrix
G	Gap and Flush	The measureable gap between two vehicle body panels; flush is how level they are relative to one another
H	HMI	Human-Machine Interface
I	IPR	Intellectual Property Rights
	ISM	Interpretive Structural Modelling
	ISO / ISO9000	International Organization for Standardization. ISO 9000 was first published in 1987, based on the BS 5750 sequence of standards from BSI that were offered to ISO in 1979.
	IRM	Initial Reachabiity Matrix
J		
K		
L		
M	Money-belt line	That area of a car around the waist of a driver, where most of the money is spent on materials for tactility and PQ.
	MIMAC	Matrice d'impact croise-multiplication en classement
	MG-R	MG Rover, car manufcturer and OEM.
N	NATO	North Atlantic Treaty Organaiation
	NPD	New Product Development
O		
P	PM	Programme Manager
	Poke-Yoke	A Japanese term, used to describe a fool-proof process.
	PQ	Perceived Quality
Q	QS9000	An industry-specific company level certification based on quality system requirements. These standards were created in 1994 by the 'Big 3' US car makers.
R		
S	SPC	Statistical Process Control, a tool used to monitor, report and control process variability.
	S&M	Sales and Marketing
	SME	Subject Matter Expert
	SSIM	Structured self-interaction matrix
T	TQI and TQM	Total Quality Initiative and Management (TQI/TQM), developed by Armand Feiginbaum.
	TS16949	together European and US standards to encompass the whole supply chain and assembly plants.
U		
V	VTS	Vehicle Technical Specification
W		
X		
Y		
Z		

Coventry Univesity Ethical Approvals

Content removed on data protection grounds