JOS VAN IWAARDEN

Changing Quality Controls

The effects of increasing product variety and shortening product life cycles

Changing Quality Controls

The effects of increasing product variety and shortening product life cycles

Changing Quality Controls
The effects of increasing product variety
and shortening product life cycles

Veranderingen in kwaliteitsbeheersing
De effecten van toenemende product variëteit
en korter wordende product levenscycli

Proefschrift

ter verkrijging van de graad van doctor aan de
Erasmus Universiteit Rotterdam
op gezag van de
rector magnificus

Prof.dr. S.W.J. Lamberts

en volgens besluit van het College voor Promoties.

De openbare verdediging zal plaatsvinden op

donderdag 28 september 2006 om 13.30 uur

door

Joos Daniël van Iwaarden

geboren te Reimerswaal

Promotiecommissie

Promotoren:
Prof.dr. B.G. Dale
Prof.dr. A.R.T. Williams

Overige leden:
Dr.ir. A. van der Wiele
Prof.dr. A. Brown
Prof.dr. A.S. Sohal

Erasmus Research Institute of Management (ERIM)
RSM Erasmus University / Erasmus School of Economics
Erasmus University Rotterdam

Internet: www.erim.eur.nl

ERIM Electronic Series Portal: http://hdl.handle.net/1765/1

ERIM Ph.D. Series Research in Management 84

ISBN-10: 90-5892-117-4
ISBN-13: 978-90-5892-117-8

Design: B&T Ontwerp en advies www.b-en-t.nl / Print: Haveka www.haveka.nl

Preface

Quality is one of those concepts that are hard to define. If you look in an encyclopedia you will find complicated definitions like "Quality refers to the distinctive characteristics or properties of a person, object, process or other thing. Such characteristics may enhance a subject's distinctiveness, or may denote some degree of achievement or excellence" (www.wikipedia.org). This kind of definition is not very helpful. On the other hand, a renowned institution like the American Society for Quality defines quality simply as "a subjective term for which each person has his or her own definition". Despite the vagueness of the quality concept, I decided to study it. I never regretted that decision.

The person with whom I first started studying the quality concept was Ton van der Wiele. Together we worked on many different projects, which has been a very valuable experience to me. I am greatly indebted to him for all his support and I wish to thank him for the good times we had over the last five years while working on papers, presentations and lectures. I hope we can continue our cooperation in the future.

Ton also was the person who introduced me to Professor Barrie Dale and Professor Roger Williams, who later became my thesis supervisors. I wish to thank them for supervising me and honestly caring about me over the last four years. They provided me with help and inspiration when I needed them. I enjoyed our meetings in Manchester and London very much, and I hope we can continue to work together for a while.

During the time of my PhD research, Roger was always able to keep abreast of the latest developments in management thinking, and he therefore had many interesting ideas for my research. However, Ton was always there to remind us of the planning with his infamous saying "a PhD is a project with a start date and an end date; both are fixed". While I was trying to strike a balance between both viewpoints, it was Barrie who told me "education is like top sport, you should peak at the right moment". Well, that is exactly what I have been trying to do in the last four years. I hope the three of you are satisfied with the result.

Other people in academia who I would like to thank are Ulrich Steimle and Professor Klaus Zink from the University of Kaiserslautern for their help with the questionnaire survey in Germany. I also would like to thank Professor Alan Brown and Professor Amrik Sohal for their useful comments on my thesis manuscript.

On a more personal level, I would like to thank my room mates Wilco and Lenny for the good times we had together. I would like to thank my family for their support and for challenging me to apply academic theories in the daily practice of the family business.

But most of all, I would like to thank my wife Lusine for her enduring love and support. At times it was difficult to both be in the process of writing a dissertation. One finished, one to go!

Jos van Iwaarden

Contents

8 CASES: A COMPARATIVE ANALYSIS 229

9 QUESTIONNAIRE SURVEY 257

List of Tables

List of Figures

1 Introduction

1.1 Introduction

Today, consumers can choose from a variety of products that is larger than ever before. At the same time, many businesses are confronted with ever decreasing product life cycles because consumers quickly feel that products are not up-to-date anymore. These two trends of increasing product variety and shortening product life cycles have implications for management control systems of firms. The aim of this research is to study their effect on one of these control systems: quality management.

In many industries (e.g. cars and electronics) manufacturing complexity and unpredictability have increased since the end of the twentieth century because of an increasing variety of products and shortening product life cycles. At the same time the manufacturers in these industries appear to have more problems with maintaining high quality levels (see Simon, 2004). It is important to understand the influence of the two trends of increasing product variety and shortening product life cycles on quality management because product variety is likely to increase in many industries and product life cycles are likely to become shorter in the future. At the same time customers will stay very demanding with respect to the quality of the products they buy. This situation will be discussed further in this chapter.

1.2 Effects of Two Trends on Quality Management

Two important trends in the current business climate are increasing product variety for customers and shortening product life cycles (e.g. Pine, 1993; Da Silveira et al., 2001; The Economist, 2001). Increasing product variety can be seen in the ever-increasing supply of and demand for alternative products and services in the market place. These days, customers can choose from many different types, colours, flavours and sizes of products. At the same time product life cycles are becoming shorter in many industries because products are being increasingly influenced by fashion trends and more severe (global) competition.

Increasing product variety and shortening product life cycles have implications for many management control systems because they require a company's management to focus its attention on a broad range of products that are updated frequently, while traditional mass production processes would require attention to only one or very few products that are produced for a long period of time.

This research studies the effect of increasing product variety and shortening product life cycles on one control system: quality management. Although quality management has often been advocated as a universal system that applies to all organizations, research has shown that it is in fact context dependent: Sitkin et al. (1994) have shown that quality management is dependent on different sources of uncertainty (task uncertainty, product/process uncertainty and organisational uncertainty), and Sousa and Voss (2001) have shown that quality management is dependent on marketing strategy (i.e. product differentiation versus cost leadership).

In order to manage quality, organizations typically aim to do three things: build relationships with customers (and other stakeholders), reduce variation in key processes, and improve processes and products in a continuous step-by-step manner (Dean and Bowen, 1994; Wilkinson et al. 1998; Handfield and Melnyk, 1998; Dale et al., 2000; Dale, 2003). So, quality management control systems are typically based on measures of customer satisfaction, reduction of variation and step-by-step continuous improvement.

However, the relevance and effectiveness of all of these are influenced by increasing product variety and shortening product life cycles. The increasing speed of change may subject the classic step-by-step Plan-Do-Check-Act (PDCA) based performance improvement loops to major strain. Since an updated product or process may already be in place before any projected improvements can be implemented (Sitkin et al., 1994). Moreover, many of the traditional tools and techniques aiming at reducing variation assume large batches of the same or similar products that are repeated over time. But batches are becoming smaller and the likelihood that a process will be repeated in exactly the same form is decreasing (Von Corswant and Fredriksson, 2002). So, the possibility of variation increasing is occurring at the same time as the basic assumptions required for traditional reduction of variation are under attack (Sitkin et al., 1994). Therefore, many of the currently used quality management systems of firms are based on assumptions that are challenged by the two trends and it is questionable whether such systems are still useful in the traditional format.

The impact on organizations of the two trends of increasing product variety and shortening product life cycles lies in their ability to increase complexity and uncertainty. The complexity is caused by the large number of different processes that require management attention (Meiners, 2006). It is clearly more straightforward to manage a single mass production process than to manage a number of production processes with large product varieties (Mukherjee et al., 2000). The uncertainty is caused by the constant flow of new product introductions and product updates, which imply that success in the market place may last only for a short period of time. Once competitors introduce new versions of their products the balance may shift again. Prater et al. (2001) point out that any business environment is a mixture of stability (predictability) and instability (adaptation to changes). Yet increasing product variety and shortening product life cycles are moving many firms towards more unpredictability and instability. Sitkin et al. (1994) argue that quality management with its focus on customer requirements, continuous improvement and the total organizational system, is basically a cybernetic control system. They go on to claim that such control systems require:

> *"A certain degree of task routineness and a moderate to high amount of certainty."*

This, according to the same authors, implies that:

> *"Cybernetic control systems are less appropriate in situations of high uncertainty."*

A more recent survey by Mehra et al. (2001) among quality experts led to the conclusion that quality management has to change radically in the short term, and that instantaneous response to changing market demands will be the single most important challenge of the future for quality management.

Consequently, to study the effects of increasing product variety and shortening product life cycles on quality management, a model is needed that can distinguish between, on the one hand, simple and stable environments and, on the other hand, complex and unpredictable environments. Existing quality models such as the Malcolm Baldrige National Quality Award Model, the European Excellence Model, and the Deming Application Prize are not appropriate for this purpose because they do not make this distinction. Therefore, there is a need to search for an appropriate model outside the quality field. This is supported by Sitkin et al. (1994), who argue that:

> *"Researchers must look beyond current approaches to total quality management for an approach to quality that can work under conditions characterized by high uncertainty and nonroutineness."*

Later on in this thesis it will be explained that Robert Simons' Four Levers of Control Model (Simons, 1995) has been chosen for this reason.

The empirical part of this research is based on case study research undertaken at three European automotive companies and a questionnaire survey among a sample of European suppliers in the automotive industry.

The automotive industry is interesting for a number of reasons:

1. The automotive industry (e.g. Toyota) has been leading edge in quality management for at least the last 25 years (e.g. Ohno, 1988; Shingo, 1989; Womack et al., 1990; Monden, 1998; Dale et al., 2000; Liker, 2004; Spear, 2004; Stallkamp, 2005).

2. Increasing product variety and shortening product life cycles are already clearly visible in the automotive industry (e.g. Pine, 1993; Womack et al., 1990; Alford et al., 2000; Agrawal et al., 2001; The Economist, 2001; Von Corswant and Fredriksson, 2002; The Economist, 2004; Sheffi and Rice, 2005). Car manufacturers introduce new models on a frequent basis and

the options lists for cars are becoming increasingly longer, although many features that, in the past, used to be options have now become standard equipment (De Saint-Seine, 2004). Life cycles of car models are under pressure because sales drop rapidly after a few years of production and even face-lifts can do little to counter this decline (Graham, 2005).

3. In an effort to retain as much as possible the operational benefits of mass production, many automotive manufacturers share platforms within brands and between brands of the same firm, or even with competing firms (Schlie and Yip, 2000). This indicates that manufacturers are trying to reduce complexity, and thereby reduce costs, by sticking to traditional mass production methods as much as possible, while on the other hand they try to offer customers the experience of a unique car (Stein, 2005; Meiners, 2005).

4. Current quality management systems are clearly under strain in the automotive industry since the number of product recalls has risen significantly (Simon, 2004). In the USA alone, product recalls in the automotive sector have risen from 208 in 1990 to 529 in 2003 (Aldred and Wernle, 2004), and the United Kingdom has witnessed a similar increase (Bates et al., 2004). To complicate matters, many of these recalls are not caused by internal problems at the car manufacturers but arise from problems at their suppliers and even at sub-suppliers (Automotive News, 2002; Kisiel, 2003; Wernle, 2004; Stoffer, 2005).

1.3 Problem Definition and Research Questions

In this section the problem definition of the research is presented. Some research questions are then derived from this problem definition. Finally, the central concepts in this thesis are defined and explained.

1.3.1 Problem Definition

The problem definition of this research is as follows:

> *How do increasing product variety and shortening product life cycles influence quality management of firms and what is the consequence of this for quality management systems?*

The problem definition, as described above, is graphically displayed in figure 1.1. Increasing product variety and shortening product life cycles are two influencing factors from the environment. These factors have a direct influence on the operational processes within the firm. As a result they also have a more indirect influence on the quality management systems of the firm (depicted by the red arrows). This latter influence is the object of this research.

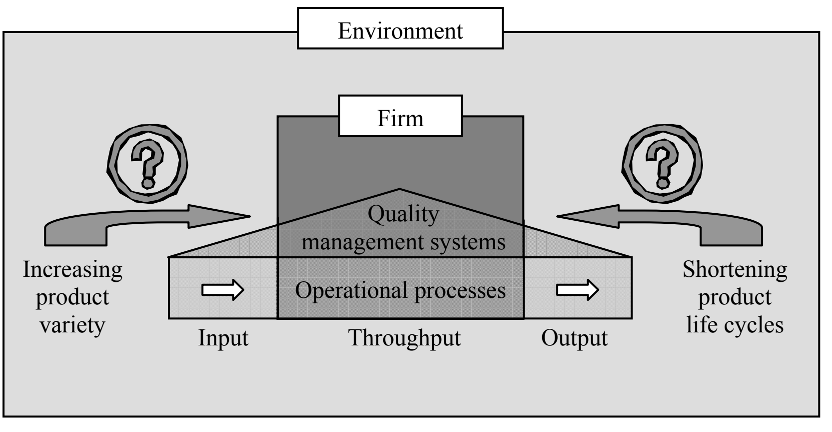


Figure 1.1: Graphical representation of the research problem definition

1.3.2 Research Questions and Objectives

Three research questions can be derived from the problem definition. The objective of this research is to find answers to the research questions. These research questions are:

1. How do increasing product variety and shortening product life cycles affect firms?

2. How do increasing product variety and shortening product life cycles influence quality management of firms?

3. To what extent are quality management systems changing in order to be capable of coping with increasing product variety and shortening product life cycles?

1.3.3 Central Concepts

The central concepts that will be used in this research are ‘quality management systems’, ‘product variety’ and ‘product life cycle’.

Bases on a review of literature in the fields of these concepts, the following definitions of these central concepts have been chosen:

- Quality management systems are defined as:
  Systems that ensure mutual co-operation of everyone in an organisation and associated business processes to produce products and services that meet and, hopefully, exceed the needs and expectations of customers.
  (Adapted from: Dale, 2003)

- Product variety is defined as:
  Providing a variety of products with the intention that more customers can find what they want at a price they can afford.
  (Adapted from: Pine, 1993)

- Product life cycle is defined as:
  The finite life span of a product that can be divided into sequential stages.
  (Adapted from: Barksdale and Harris, 1982)

Quality management

The reason why companies offer quality is to satisfy the customer (Dale, 2003). Total Quality Management (TQM) is defined in ISO 9000:1994 (ISO, 1994) as:

> *"A management approach that tries to achieve and sustain long-term organizational success by encouraging employee feedback and participation, satisfying customer needs and expectations, respecting societal values and beliefs, and obeying governmental statutes and regulations."*

Ishikawa (1985), one of the famous quality experts, emphasised the focus on the customer:

> *"To practice quality control is to develop, design, produce and service a quality product that is most economical, most useful and always satisfactory to the customer."*

Companies that do not continually satisfy their customers will lose those customers and as a result they will achieve poor performance. Quality is seen as essential for strategic success because poor quality will lead to losses of profitability and market share (Garvin, 1988). Companies need to improve their quality to satisfy the ever-increasing demands of customers. There is a trend that customers want more value for less money. So, quality management and continuous improvement are necessary for companies to stay competitive in the market place. Cox and Dale (2001) state:

> *"The key element to business achievement is quality. Without a quality management approach that guarantees quality from its systems, staff and suppliers, a business will not be able to deliver the appropriate level of service quality to satisfy its customers. In any industry customer loyalty is a key factor in gaining a competitive advantage over the competition."*

Product variety and product life cycle

Product variety is the number of different types of a product that are available to customers. So, it is not just about the total number of different products in the market place but more about the number of types of a product. The greater this variety of product types is the more choice customers have. The above-mentioned definition of product variety requires that the variety of product types should be available at an affordable price. That means that the option to customise certain products for a large amount of money is not regarded as more product variety.

A product life cycle is the finite life span of a product that can be divided into sequential stages (Barksdale and Harris, 1982). These stages are used to analyse the (future) development of a product. The product life cycle is usually divided into the following five phases: launch, early growth, late growth, maturity, decline (Karlof, 1993).

1.4 Scientific and Managerial Relevance

In this section the relevance of this study is discussed. It is argued that the study has scientific, as well as managerial relevance.

1.4.1 Scientific Relevance

The scientific relevance of this research project lies in studying the influence of two important trends (i.e. increasing product variety and shortening product life cycles) on quality management. As far as we are aware, nobody has looked from a scientific point of view at the issues of product variety and product life cycles in relation to quality management. Nor has anyone used Simons' control model (Simons, 1995) to study the quality management discipline. As such, these innovations can both contribute to scientific literature.

Furthermore, it is relevant to empirically test if the traditional fundaments of quality management are still appropriate in current business climate. The environment in which organisations operate is subject to constant change and therefore it is necessary to adapt quality management approaches to remain effective under the changed circumstances. Bisgaard and De Mast (2006) argue that:

> *"The world keeps changing. Quality management will therefore always need to be improved and adapted to the changing circumstances. Thus, we constantly need to experiment with new ideas."*

1.4.2 Managerial Relevance

Over the last decade many business sectors (e.g. the automotive, food, beverages, clothing, electronics, and personal care industries) have moved away from traditional mass production, which aims at manufacturing large volumes of the same product, towards offering a variety of products in low volumes. Moreover, the markets in which these businesses operate have moved from long and stable life cycles towards much shorter and unpredictable life cycles (Pine, 1993). These shifts have major consequences for managing companies in these business sectors. Based on the underlying assumptions of quality management, it can be expected that the trends in product variety and product life cycles affect the usefulness of traditional quality management systems. Therefore, it is necessary to undertake empirical research on the usability of existing quality management systems in changing environments. As it is expected that quality management systems need to be changed drastically (Mehra et al., 2001), empirical research could also indicate the necessary changes. Only if quality management systems are based on assumptions that are in line with reality, can they be expected to be useful in practice. So, the need to carry out empirical research in this field is not only based on theoretical considerations but also on everyday business practice. Satisfying the customer should remain a top priority for companies because it is still an effective competitive weapon.

1.5 Research Boundaries

This research has been conducted within certain boundaries. One boundary is the focus on the effects of the two defined trends with respect to product variety and product life cycles. In the empirical part of the research it has been attempted to distinguish the effects of product variety and product life cycle trends from other influences on quality management. To achieve this, care has been taken when designing the research methodology, which will be explained in detail in chapter 4. However, no research methodology will be able to completely isolate the effects of the two studied trends from other influences because of the complex and interdependent context in which companies operate.

Another boundary of this research is that the two trends of product variety and product life cycles will be taken as a given. This means that no attempts will be made to explain all possible economical, social and cultural causes for the two trends. Neither will be judged whether the two trends are beneficial to society, e.g. whether customers are actually asking for a large variety of products to choose from or if it is mostly driven by marketers from companies (see Avishai and Taylor, 1989).

A third boundary of this research is the focus on quality management. The two trends of product variety and product life cycles will influence many more things than just quality management. Some examples from the automotive industry are showroom space, which will get scarce at automotive dealerships when many different car types are offered (the larger the variety of car models, the smaller the available floor space per car model will be), and availability of replacement parts for cars (the shorter the product life cycles become, the more different types of spare parts are needed to repair existing cars). So, this research has only studied the effects of the two trends on the management of quality by companies. More specifically, the research deals with the management of the quality of physical products, as opposed to services. The empirical part of the research has focused on how different actors in assembly supply chains manage the quality of their products and deal with quality problems they encounter. However, the focus on physical products does not mean that managing quality is only related to physical defects, since it is also related to dissatisfied customers because of more intangible quality issues that may result from physical products.

1.6 Outline of the Dissertation

The remaining chapters in this dissertation are structured as follows:

Chapters 2 and 3 provide an overview of theory on quality management (chapter 2) and management control (chapter 3). These chapters describe the theoretical context in which this research takes place.

Chapter 4 explains the methodology for the empirical part of the research. It describes how the case studies and the questionnaire survey contribute to finding an answer to the problem definition.

Chapters 5, 6 and 7 present the findings from three case studies at three European automotive manufacturers. Each of the three chapters describes one complete case study of an automotive manufacturer and some of its suppliers.

Chapter 8 discusses the findings from the case studies by comparing the three cases and drawing conclusions.

Chapter 9 discusses the questionnaire survey that has been conducted after the case studies were completed. The design of the questionnaires is described, as well as the findings of statistical analyses on the questionnaire data.

Chapter 10 presents the overall findings of the research and draws final conclusions.

An overview of the structure of this dissertation is presented in figure 1.2.

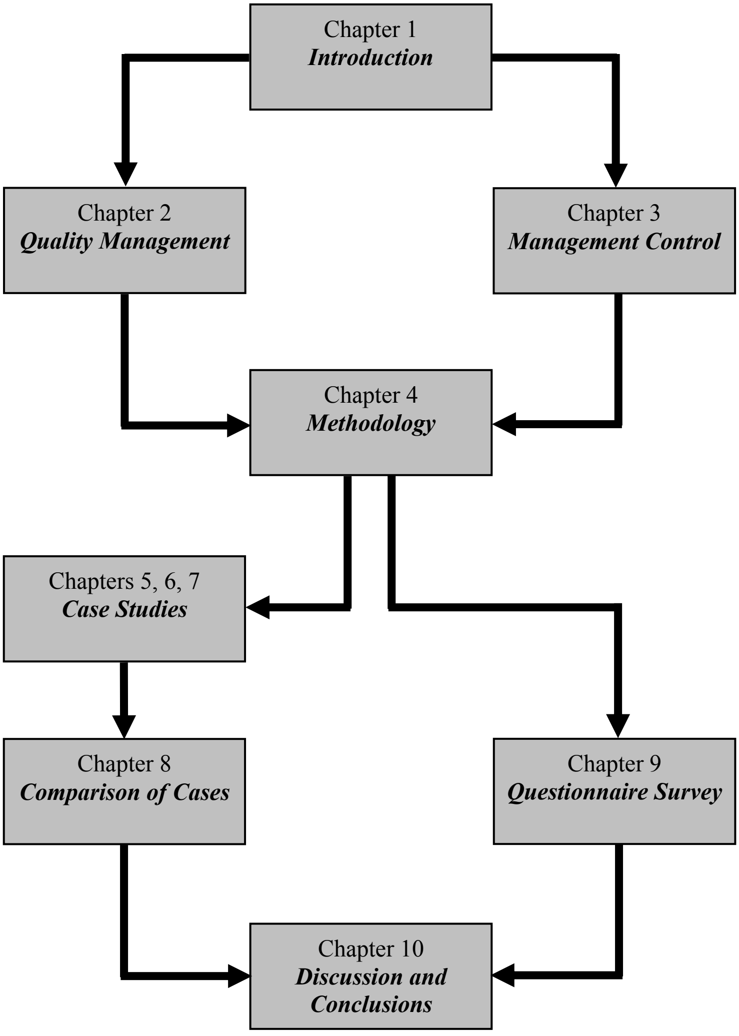


Figure 1.2: Outline of the dissertation

1.7 Summary

In this chapter the research project has been introduced. The research deals with the effects of two trends on quality management of firms. These two trends are the increasing number of product variations that companies offer to customers, and the decreasing length of product life cycles. Product variety has been increasing because of fragmented markets and demand for more individualised or customised products, and because many companies realise that they can attract more customers by developing products that are more in line with their needs and wants. Product life cycles have become shorter because many products are subject to fashion trends and customers quickly switch to another product from another company. The extent to which increasing product variety and shortening product life cycles affect companies differs per industry sector. Industry sectors that already feel the impact of these two trends are, for example, the automotive, food, beverages, clothing, electronics, and personal care industries.

This research deals with the question how the two trends of increasing product variety and shortening product life cycles influence quality management and what consequences this has for quality management systems. To answer this question empirical research has been undertaken by means of case studies at three European automotive companies and a questionnaire survey among a sample of European companies in the automotive industry. The methodology and results of this empirical research will be discussed in the remainder of this thesis, after a review of literature on quality management and management control.

2 Quality Management

2.1 Introduction

The aim of this chapter is to describe the major developments that have taken place over time in the area of quality management. This chapter starts with a description of the evolution of quality management. Then the efforts of researchers to develop a quality management theory are described. Thereafter, the core building blocks of quality management are explained. It is then argued that the two trends of increasing product variety and shortening product life cycles have an influence on these core building blocks. Finally, it is argued that a suitable model to study the effects of increasing product variety and shortening product life cycles on quality management is not available in the quality field and should therefore be found in the broader management control field.

2.2 The Evolution of Quality Management

The way quality management is practised by organisations has developed over time. In recent history, four fairly discrete stages in the evolution of quality management can be identified (Dale, 2003; Van der Wiele, 1998):

1. Inspection
2. Quality control
3. Quality assurance
4. Total quality management

Each of these stages will be described below. The first two stages are based on detection of quality problems (i.e. finding and fixing mistakes), while the last two are based on prevention of quality problems. The hierarchical progression in the four stages of quality management is graphically displayed in figure 2.1.

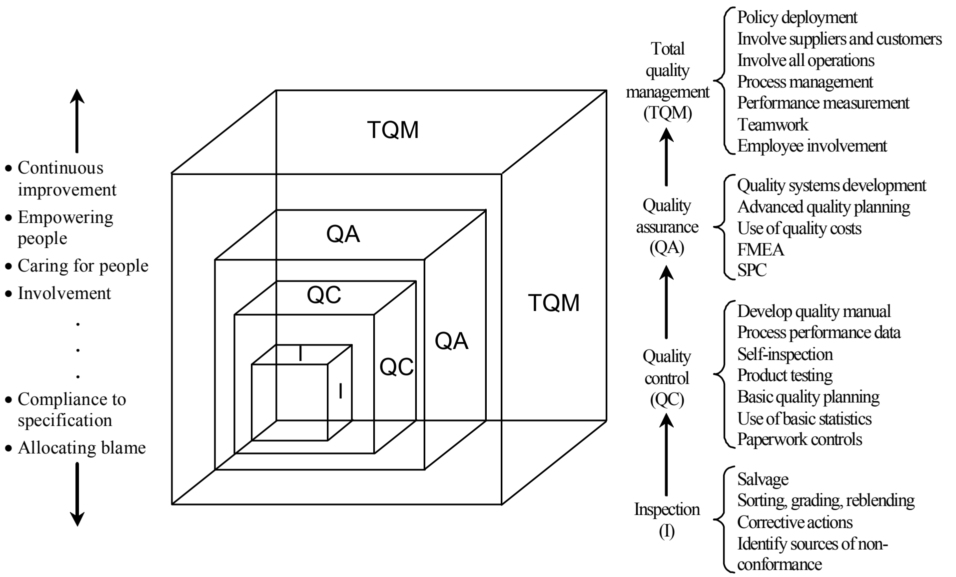


Figure 2.1: The four stages in the evolution of quality management (source: Dale, 2003)

2.2.1 Inspection

Quality inspection means that one or more characteristics of a product, service or activity are examined, measured, tested, or assessed and compared with specified requirements to assess conformity against a specification or performance standard (Dale, 2003). Inspection can take place in both manufacturing and service environments. Manufacturing organisations can inspect incoming goods, sub-assemblies during the production process, and final products before they are delivered to the customers. In service organisations inspection can take place at key points, sometimes called appraisal points, in the production and delivery process. Inspections can be done by specialised staff or, in the form of selfinspection, by employees who are responsible for a certain product or process. The system is a detection-based quality system that does not by itself prevent quality problems from reoccurring.

2.2.2 Quality Control

The stage of quality control is more advanced than the inspection stage, although it is still based on detection of quality problems (Dale, 2003). A system of quality control will typically have detailed product and performance specifications, fixed inspection points in the process, and feedback of process information to relevant stakeholders. So, while inspection systems are strongly focussed on the product, quality control systems are more focussed on the processes from which these products originate. A drawback of quality control systems is that they may lead employees to believe that they can rely on their work to be checked. Consequently, these employees may not feel stimulated to prevent quality problems or improve the processes for which they are responsible (Van der Wiele, 1998).

2.2.3 Quality Assurance

Solving quality problems after they occur is not very efficient and therefore the next quality stage (i.e. quality assurance) aims to prevent quality problems from occurring (Dale, 2003). So, this is a prevention-based quality system. A quality assurance system is focused on providing confidence that an organisation will comply with quality requirements. Quality assurance systems have a wider focus than quality control systems because they move from a process focus towards a system focus, which means that they encompass multiple processes to increase uniformity and conformity.

2.2.4 Total Quality Management

The fourth stage in the quality management development hierarchy is total quality management (TQM). TQM involves the application of quality management principles at every level in an organisation and to all aspects of an organisation (Dale, 2003). TQM is a company-wide approach to quality with a balance between technical, managerial, and people issues. The individual quality tools and techniques in the TQM stage may be the same as in the quality assurance stage but in the TQM stage they affect every person, activity and function of an organisation.

2.3 Quality Management Theory

The most widespread used quality management systems are the ISO 9000 series and the Business Excellence Models (like the Malcolm Baldrige National Quality Award Model in the USA, the European Excellence Model in Europe, and the Deming Application Prize in Japan). Although these systems are based on hypothesised relations between variables, the theory behind quality management is not very explicit. This is the result of the fact that quality management has been mainly led by practitioners (Sousa and Voss, 2002).

A small group of quality experts (Deming (1986), Juran (1945), Feigenbaum (1986), Crosby (1979) and Ishikawa (1985)) substantially influenced the early development of quality management (Kruger, 2001). Although these experts developed implementation plans for quality management they did not develop scientific theories (Bryce, 1991; Dean and Bowen, 1994; Dale et al., 2001). However, the approach of the experts was based on management theory. Elements of scientific management theory (Taylor, 1911; Rogers and McIntire, 1983; Shafritz and Ott, 2001) can be found in the early thinking about quality (Wilkinson et al., 1998; Bryce, 1991). Some of the basics of scientific management theory are cooperation instead of individualism, harmony instead of discord, maximum output instead of restricted output, and science instead of rule of thumb. The quality experts also adhered to these principles. Deming's statistical process control is an example of applying science to management instead of rule of thumb.

2.4 Quality Management Systems

Following on from the early thinking of the experts, which focussed on problem solving and improvement of products and processes, quality management systems have been developed that have a broader view on quality management and that have a more preventive focus. Quality management thinking has evolved from a narrow focus on statistical process control to a variety of technical and behavioural methods for preventing problems to occur and improving organisational performance. The ISO 9000 series and the Business Excellence Models have proven to be very popular in business practice. These models prescribe certain actions and behaviours that should lead to excellent quality and performance (Dean and Bowen, 1994). However, these models do so without explicitly stating a theory that underlies these prescriptions. This is, as argued before, a result of the fact that quality has been mainly led by practitioners (Sousa and Voss, 2002).

If management theories are prescriptive they tend to be contingent (i.e. sensitive to variation in the organisational context). However, it is hypothesised that quality management recommendations are context independent and therefore implicitly universal (Spencer, 1994). In general, quality management pays little attention to the boundary conditions for the applicability of quality management, nor does it pay attention to how variation in organisational settings might be reflected in quality management implementation (Sitkin et al., 1994). Therefore, it seems that a contingency theory approach is necessary in quality management. More recent research by Sousa and Voss (2001) has shown that quality management is in fact context dependent. Contingency theory is based on the proposition that an organisation's relationships with other organisations, as well as its relationship with its total environment, depend on the situation (Hodge and Anthony, 1988). Thus contingency theory rejects all-purpose principles and constructs.

2.5 Efforts to Develop Quality Management Theory

Quality management takes a very broad view of management and therefore involves a number of different (implicit) theories. The absence of a single quality theory makes it necessary to study quality management from an approach that involves using multiple theories. However, in the last decade researchers have started to develop quality management theory (Dean and Bowen, 1994; Anderson et al., 1994; Waldman, 1994; Handfield and Melnyk, 1998; Tam, 2000; Behara and Gundersen, 2001; Sousa and Voss, 2002). Many of these theory development efforts are based on the existing quality management systems (Behara and Gundersen, 2001). Therefore, they build on the same three core principles as the quality management systems. These core principles are customer focus, reduction of variation in organisational processes and continuous improvement (Dean and Bowen, 1994; Wilkinson et al., 1998; Handfield and Melnyk, 1998; Dale et al., 2000; Dale, 2003). In section 2.6 these three principles will be explained in more detail.

The efforts to develop a quality management theory based on the existing quality management systems lead to a combination of several management theories that could be applied in relation to the quality management systems (Dean and Bowen, 1994). However, a large number of theories is not very helpful in guiding a research project. Therefore, it is probably more useful to focus on the three before mentioned principles of quality management (customer focus, reduction of variation in organisational processes and continuous improvement) because these form the core building blocks of quality management. In order to manage quality, organisations typically aim to do three things: build relationships with customers (and other stakeholders), reduce variation in key processes, and improve processes and products in a continuous step-by-step manner (Dean and Bowen, 1994; Wilkinson et al. 1998; Handfield and Melnyk, 1998; Dale et al., 2000; Dale, 2003). So, quality management control systems are typically based on measures of customer satisfaction, reduction of variation and step-by-step continuous improvement. Consequently, focusing on these three core principles of quality management has the advantage of limiting the number of theories used, while still capturing the core principles of quality management.

2.6 Core Building Blocks of Quality Management

As argued in the previous sections, quality management research has until now not paid much attention to organisational contingencies that may affect the application of quality management. Since the quality management discipline has been built upon three core building blocks that are major components of any quality management strategy, it is important to understand how different organisational environments affect the way these building blocks are applied. The efforts of the last decade to build theories around the three building blocks have not resulted in one agreed approach. Therefore, for our research there is no basic quality management theory available that captures all three building blocks. Consequently, our research focuses on each of the three building blocks, which are discussed below.

2.6.1 Customer Focus

Customer focus is about the relationship between the supplier and the customer. Quality management can be seen as a system to ensure that the customer receives the products that he wants, when he wants them, and at an acceptable cost. Focusing on the customer starts with listening to the customer, in order to understand his demands and needs. An organisation can then develop and offer products that fulfil the customer’s demands and needs.

Customer focus implies that the success of any firm depends above all on the customer (Foxall and Goldsmith, 1994). Cox (1997) explains that customer focus means looking at quality from a customer standpoint.

A.T. Kearney (1994) defines customer focus as:

> *"The sum of every relationship a firm has with every customer."*

The authors conclude that the process of achieving competitive advantage by means of total customer satisfaction never ends and has three phases: beginning, attaining and retaining. Customer focus begins by determining exactly what customers want and directing all efforts to their accurate expectations. Attaining competitive advantage entails exceeding customers' expectations in the most crucial areas of service considered by customers. Retaining competitive advantage means that organisations have to maintain their focus on the customer and continuously adapt it when needed.

2.6.2 Reduction of Variation in Organisational Processes

Reduction of variation in organisational processes aims to provide customers with constant quality and at the same time reduce costs. In a situation of large variations in processes and quality, customers can either receive high quality products or low quality products. Although the high quality products will satisfy customers, the low quality ones will dissatisfy them. Therefore, quality management aims to reduce these variations and offer products of a constant quality. The study of variation in (organisational) processes is the object of study of statistics. So, a statistical approach forms the roots of the quality thinking about reduction of variation in organisational processes (Shewhart, 1931). Many of the quality experts emphasise the need for statistical process control and reduction in variation of organisational processes (Deming, 1986; Feigenbaum, 1986; Juran and Gryna, 1988). Shewhart (1931) was one of the first people who wrote about statistical process control. The basic idea of Shewhart was that all manufacturing processes display variation. This variation consists of two components: a steady component that is inherent to the process and has no assignable cause, and an intermittent component that has assignable causes. The intermittent component can be economically discovered and removed from the process, while the steady component cannot be economically removed from the process. Removal of the intermittent component will reduce variation in the processes and therefore will reduce fluctuations in quality.

Statistical process control is a powerful technique which organisations can use to reduce the variation in their processes (Antony and Taner, 2003). These authors defined statistical process control (SPC) as:

> *"An integral part of monitoring, managing, maintaining and improving the performance of a process through effective use of statistical methods."*

In their work, Antony and Taner (2003) identified problems with inspection-based quality control. They regard inspection as an activity that is often expensive, unreliable and provides little information as to defects occurred and how they can be corrected. They suggest overcoming these problems by applying preventive techniques in an organisation's operations to ensure that products are produced to the required quality standards. The authors go on to claim that such an approach requires the application of statistical methods to monitor, analyse, manage and improve the process performance, and thereby to improve product quality.

Even though the principles of process control are old, they have not yet lost their importance to organisations. Currently, there is an interest in the Six Sigma improvement approach (see Bhote and Bhote, 1991; Pande et al., 2000; Pyzdek, 2003), which incorporates many of the principles of statistical process control (Bisgaard and De Mast, 2006).

2.6.3 Continuous Improvement

Continuous improvement in quality management implies looking at the consequences of an organisational process or at the features of a product and then applying what has been learnt to the next cycle of the same process or the next batch of the same product. So, this involves a feedback loop, which means that by learning from the consequences of previous actions, the next action on the same process can be amended (Stacey, 1996; Garvin, 2000).

According to Deming (see Bhuiyan and Baghel, 2005), continuous improvement is a philosophy that consists of:

> *"Improvement initiatives that increase successes and reduce failures."*

However, this is a very general definition. The definition of Bhuiyan and Baghel (2005) is more specific about what continuous improvement means to organisations:

> *"A culture of sustained improvement targeting the elimination of waste in all systems and processes of an organization. It involves everyone working together to make improvements without necessarily making huge capital investments."*

Continuous improvements can result in significant quality improvements and reduction of waste. However, Caffyn (1999) warns organisations that the process of implementing a continuous improvement program can be long and challenging.

2.7 Effects of Product Variety and Life Cycle Trends

Looking at the building blocks of quality management, the hypothesised effects of increasing product variety and shortening product life cycles can be made clear.

2.7.1 Customer Focus

The wishes and demands of the customers should be the input for a firm when deciding what products or services to provide. When these wishes and demands are homogeneous, this should not be too difficult for firms. However, when they are heterogeneous, it could be very difficult to provide each customer with the products and services that he or she wants. So, in a situation of short product life cycles and a large product variety, it is questionable how well quality management systems are able to maintain a focus on each of the many customers who are looking for a customised product.

Customer wishes could become volatile when an increasing number of different products is available on the market. When products are frequently updated, customers will get used to the latest possibilities and technologies. Moreover, they will quickly start to regard them as standard, and consequently expect them to be offered by all competing manufacturers.

Cox (1997) argues that in a situation in which product life cycles are getting shorter and products variety is increasing, it is necessary for organisations to remain customer focused. He argues that there is a need to anticipate customer requirements and to workout systems and platforms that they will need for the future. Cox (1997) stated that an organised customer base is a great power if an organisation understands it and has the right systems to make best use of it. Both will be an important challenge for an organisation operating in a dynamic and complex environment. Means of market access in terms of reaching customers have changed, because there are new product outlets and means of contacting customers.

2.7.2 Reduction of Variation in Organisational Processes

Reduction of variation in organisational processes implies that production takes place in large batches of the same or similar products and that production processes last for a relatively long time without changing (Sitkin et al., 1994). Shewhart (1931) states that the intermittent part of the variation of manufacturing processes can be economically discovered and removed. In the case of large batches of the same products that are repeated over time, this is indeed possible. However, increasing product variety and shortening product life cycles are causing the batch sizes to become smaller and the probability that the same process will be repeated in the future is also becoming smaller (Von Corswant and Fredriksson, 2002). This makes it increasingly hard to apply statistical process control to reduce variation in organisational processes. It is getting difficult to economically discover and remove the intermittent part of the variation of manufacturing processes if there are many small processes that will last only a short time.

Using statistics in the operational processes implies that data are available. However, when the number of product variants is very high, not all variants will be frequently sold to customers. Consequently, the manufacturer will have very little data available about these specific variants, which will make it very difficult to perform analyses.

2.7.3 Continuous Improvement

Continuous improvement implies that changes occur gradually and that processes can be incrementally improved (i.e. the Japanese Kaizen) (Imai, 1986; Bryce, 1991). It also implies that the same production processes are repeated over time. This means that a feedback loop is necessary to improve the processes. A firm learns from the current production process and applies what it learnt directly to the next cycle of the same production process, which is (nearly) identical to the previous one. This is a static, routine way of learning. It is about the recognition of a similar situation. However, increasing product variety and shortening product life cycles will make this literal replication of little value because these trends will cause major changes in organisational processes. When processes are significantly different, the value of literal replication of what has been learnt in one process is probably much lower for the other process. Therefore, it will no longer be sufficient to simply replicate what has been learnt in a previous process. So, the speed of the feedback loop is crucial. What has been learnt from an organisational process will have to be applied very quickly to the same process while it is still the same. If what has been learnt cannot be applied quickly enough, the process will probably already have changed. The question is whether firms are able to speed up their learning sufficiently to be able to apply what has been learnt to the same process.

2.8 Selecting a Suitable Model

The previous sections have shown that the general consequence for companies of increasing product variety and shortening product life cycles is a shift from relatively simple and stable environments towards more complex and unpredictable environments.

Therefore, to study the effects of increasing product variety and shortening product life cycles on the management and improvement of quality, a model is needed that can cover, on the one hand, simple and stable environments and, on the other hand, complex and unpredictable environments. Existing quality models like the quality award and business excellence models (e.g. the Malcolm Baldrige National Quality Award Model, the European Excellence Model, and the Deming Application Prize) are not appropriate for this purpose because they do not make this distinction. These models may be broad enough to capture environmental factors in the practical application of quality thinking in organisational settings. However, they are by nature universalistic because they are aimed at comparing the quality performance of different organisations, regardless of the specific characteristics of these organisations and of the environments in which they operate (Sousa and Voss, 2001). Therefore, it is necessary to search for an appropriate model outside the quality field (Sitkin et al., 1994).

As indicated before, it can be argued that quality management consists of three core building blocks, which are customer orientation, process control, and continuous improvement (e.g. Dean and Bowen, 1994; Wilkinson et al. 1998; Handfield and Melnyk, 1998; Dale et al., 2000; Dale, 2003). Based on these three building blocks it can further be argued that quality management can be seen as a management control system since it is aiming to control an organisation's processes and to improve and change these processes in response to market changes. Therefore, a logical place to look for a model is in the field of management control. The next chapter will review the management control literature, with the aim to find a suitable model that can in fact make the distinction between, on the one hand, simple and stable environments and, on the other hand, complex and unpredictable environments.

2.9 Summary

In this chapter relevant quality management literature has been reviewed in order to describe the field of study in which this PhD research takes place.

The evolution of quality management from inspection, via quality control and quality assurance, towards total quality management has been described. It has been argued that the early developments in quality management have been influenced strongly by the thinking of a small number of quality experts (i.e. Deming, Juran, Feigenbaum, Crosby and Ishikawa). These experts were very much concerned with the practical application of quality management but did not develop scientific quality management theories. The well known quality management systems, like the ISO 9000 series and the various Business Excellence Models, are also not strongly based on theory. However, in the last decade researchers have started to develop quality management theory. This has led to a combination of several management theories that could be applied in relation to quality management. It has been argued that these efforts are basically focussed on three core principles of quality management systems, which are customer focus, continuous improvement and reduction of variation in organisational processes.

These three core principles will also form the basis for studying quality management in this research. Focusing on the three core principles of quality management has the advantage of keeping the number of theories used limited, while still capturing the core of quality management. For each of the three core principles it has been shown that increasing product variety and shortening product life cycles may lead to difficulties for managing quality.

The consequence for companies of increasing product variety and shortening product life cycles is a shift from relatively simple and stable environments towards more complex and unpredictable environments. Therefore, to study the effects of increasing product variety and shortening product life cycles, a model is needed that can distinguish between different kinds of environments. It has been argued that existing quality models cannot make this distinction. Consequently, it is needed to look in the wider management control field for a suitable model, which will be done in chapter 3.

3 Management Control

3.1 Introduction

This chapter presents an overview of developments in the area of management control. It shows that a major issue in management control research is the effectiveness of management control systems under different circumstances. Many organisational and external factors affect the effectiveness of management control systems. Major research has been done in this area by Simons (1987; 1991; 1994; 1995; 2000). He developed a model (Simons, 1995; Simons, 2000) that combines the design of management controls systems with the strategy of an organisation. Since this model will be used for the empirical part of this research (see chapter 4), the model and its implications are explained in this chapter.

3.2 Developments in the Area of Management Control

One of the major functions of management is to ensure that strategies and plans are carried out. This is called the control function of management (Merchant, 1982). Many definitions of management control have been used in literature. A major distinction between different definitions is the extent to which management control is believed to be externally influenced (see Otley et al., 1995). For example, Lowe (1971) suggested a comprehensive definition of management control, which clearly incorporates the influence of the environment on management control:

> *"A system of organizational information seeking and gathering, accountability and feedback designed to ensure that the enterprise adapts to changes in its substantive environment and that the work behaviour of its employees is measured by reference to a set of operational sub-goals (which conform with overall objectives) so that discrepancy between the two can be reconciled and corrected for."*

On the other hand, Machin (1983) provides a definition of management control that is internally focussed, and does not take external influences on organisations into account:

> *"The process by which managers assure that resources are obtained and used effectively and efficiently in the accomplishment of the organization's objectives."*

Other elements of different management control definitions are managers' abilities to influence employees (Harzing, 1999), and the measurement of organisational performance (Kamm, 1980).

The first element, managers' abilities to influence employees, can be found in Anthony's (1988) definition of management control:

> *"The process by which managers influence other members of the organization to implement the organization's strategies."*

The second element, measurement of organisational performance, can be found in Kamm's (1980) definition of management control:

> *"The set of criteria, policies and procedures established to standardize operations and to make possible measurement of performance to ensure achievement of organizational objectives."*

Kamm's definition shows that management control contains element that are very similar in approach to elements of quality management, both aim to standardise operations, measure performance, and adjust operations to correct for deviations from agreed standards.

According to Merchant and Simons (1986), definitions of management control generally contain two key concepts:

> *"A focus on the behaviour of organizational participants and a concern with the effect of this behaviour on organizational outcomes."*

Although there currently is a large amount of literature on management control, it has only received serious research attention since the second half of the twentieth century (e.g. Arrow, 1964; Anthony, 1965). However, the concept of control has been around for much longer than that. Control is seen as the central idea of Taylor's scientific management (Giglioni and Bedeian, 1974; Otley et al., 1995). Reasons why research into management control had not taken off until the last half of the previous century are the mistaken belief that control is the sole domain of accountants and controllers, and the many different meanings the control concept has in different languages, different contexts and different countries (Rathe, 1960; Giglioni and Bedeian, 1974). Otley et al. (1995) argued that an unintended consequence of Anthony's (1965) work has been that management control has remained unnecessarily restrictive. Therefore, these authors propose a broad view of what constitutes management control. For the research in the present study, we will adapt a broad view of management control as well, in line with Merchant and Simons (1986).

The strong link between management control and scientific management indicates that the roots of management control and quality management are closely related, since the early thinking on quality management was also similar to many of the scientific management ideas (Wilkinson et al., 1998; Bryce, 1991). The focus of the early management control research is similar to quality management research as well. Both dealt with real problems, and were aimed at understanding and solving these problems (see Otley et al., 1995; Dean and Bowen, 1994).

3.3 Management Control Systems

Organisations use management control systems to maintain control over their processes. Simons (1994) defines management control systems as:

> *"The formal, information-based routines and procedures used by managers to maintain or alter patterns in organizational activities."*

These management control systems tend to be designed according to a cybernetic philosophy. According to Hofstede (1978), this means that they operate by:

> *"Setting goals, measuring achievement, comparing achievement to goals, feeding back information about unwanted variances into the process to be controlled, and correcting the process."*

This definition shows that management control systems are very similar to many quality management systems, in the sense that they both are cybernetic systems (see Sitkin et al., 1994).

3.4 Management Control in Different Environments

One of the most important themes in management control research is the explanation of differences in management control systems between organisations operating in different environments (Chenhall, 2003; Speklé, 2001). Extensive research has been done on the effects of differences in the nature of the environment, technology, firm size, structure, strategy and national culture on the effectiveness of management controls systems (see Chenhall, 2003). Most of this research has focused on the effects of the external environment and corporate strategy on management control systems. It is believed that certain management control systems are more suited to certain environments and strategies than others (Chenhall, 2003). Simons (1987; 1990; 1991; 1994) has conducted important research in this area and developed his 'four levers of control' model (Simons, 1995) on the basis of this research.

One of the most widely used aspects of the organisational context is uncertainty (Chenhall, 2003). In the literature, the concept of uncertainty has been related to environment and technology. According to Ditillo (2004), literature shows that environmental uncertainty can be captured in terms of dynamism, heterogeneity, predictability, controllability and equivocality. Technology has been associated with complexity, task uncertainty and interdependence (for references to literature that explains these terms, see Ditillo, 2004, p. 407).

Management control systems have been found to be important systems for obtaining information in order to reduce uncertainty in environments characterised by high levels of uncertainty (Davila, 2000). According to Khandwalla (1972), the confidence in formal systems increases with the intensity of competition. Chenhall and Morris (1986) argued that managers who perceive a higher level of environmental uncertainty tend to use a broad scope and more timely and more external information. Simons (1994) argued that the type of control systems used in an uncertain environment differs from the type of control systems used in a stable environment (see section 3.5).

The current high product variety and shortening product life cycles put great pressure on new product development. Research on new product development has documented three types of uncertainty: market-related, technology-related and project scope. Davila (2000) assumed that the major role of management control systems in product development is to supply information that is required to reduce uncertainty rather than to reduce goal divergence problems. He found that uncertainty and product strategy are related to the design and use of management control systems. He also found that alignment between the design and use of management control systems and strategy is significantly related to performance.

In 2004, Ditillo introduced a new variant of uncertainty which is knowledge complexity. The author examined the impact of knowledge complexity on management control systems in knowledge-intensive firms. Knowledge-intensive processes involve extra uncertainty, because they require the application of a broad range of differentiated knowledge that needs to be integrated to produce appropriate responses to customers' needs. Ditillo found that management control mechanisms are to be designed to both coordinate individuals and to support knowledge integration at the same time. Ditillo's analysis concluded that knowledge complexity is a relevant factor in explaining the variation of management control systems between organisations.

Many research papers revealed significant relationships between business strategy and selected environmental and management control system attributes (Sim and

Teoh, 1997). Many different strategic types have been used in empirical research, however, the categorisation of Miles and Snow (1988) is the most widely applied (Sim and Teoh, 1997). Miles and Snow (1988) distinguish four strategic orientations:

1. Prospectors: firms that constantly seek new marketing opportunities and compete through new product-market innovations.

2. Defenders: firms that operate in relative stable market spheres and compete predominantly on the basis of price, quality and service.

3. Analysers: firms that combine the characteristics of prospectors and defenders. So, they operate partly in stable markets and partly in new markets.

4. Reactors: firms with no consistent strategy, which are viewed as unstable and non-viable.

Miller and Friesen (1982) found that control and innovation were positively correlated for conservative firms (or defender firms) and negatively correlated for entrepreneurial firms (or prospector firms). Sim and Teoh (1997) used three dimensions of environment (dynamism, hostility and heterogeneity) to investigate the relationship between control system attributes, business strategy and environment in three countries. They found that control system attributes and environmental characteristics were significantly related to strategy types of defender, prospector and analyser.

Summarising, it has become clear from this section that the type of control system varies with the environment. As argued before, Robert Simons has undertaken major research into this relationship, which will be discussed in the section 3.5. The fact that many research findings are available on the relationship between environment and control systems, sets management control apart from the quality management discipline. In the quality management discipline, contingency-based research has traditionally received little attention (Spencer, 1994; Sitkin et al., 1994), while it has been an important part of management control studies for a long time (see Bell, 1965; Khandwalla, 1973; Hayes, 1977). Therefore, we aim to make use of the long experience with contingency-based research in the management control discipline, by applying a major management control model to quality management research. This management control model is explained in section 3.5.

3.5 Effects of Product Variety and Life Cycle Trends

The previous chapters have shown that the general consequence for companies of increasing product variety and shortening product life cycles is a shift from relatively simple and stable environments towards more complex and unpredictable environments.

Therefore, to study the effects of increasing product variety and shortening product life cycles on quality management, a model is needed that can distinguish between, on the one hand, simple and stable environments and, on the other hand, complex and unpredictable environments.

Such a model that can distinguish between, on the one hand, simple and stable environments and, on the other hand, complex and unpredictable environments, is Simons' four levers of control model (Simons, 1995). This model is used in the management control literature (Ramos and Hidalgo, 2003; Bisbe and Otley, 2004). According to Bruining et al. (2004):

> *"Simons' model of the dynamic relationships between management control systems and strategic change is an attempt to offer a coherent and comprehensive body of management control theory."*

Given this model's suitability to study the influence of increasing product variety and shortening product life cycles on quality management, it is used for the empirical part of this research. The model is accepted in the management control field, however, it has not been used before in the field of quality management. Still, the model's adequacy for analysing important real world phenomena means that it is appropriate to use it outside its original field (Feldman, 2004).

Simons' four levers of control model is displayed in figure 3.1.

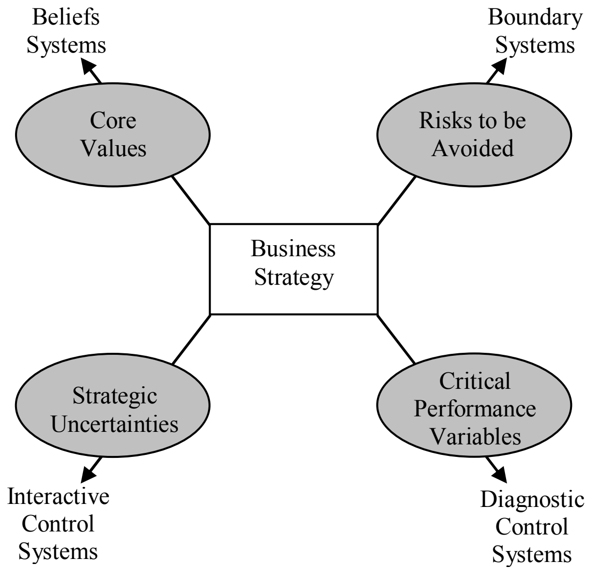


Figure 3.1: Simons' four levers of control model (Simons, 1995)

Simons' four levers of control model is used to balance control mechanisms in an organisation in order to realise the business strategy. These control mechanisms are broadly defined, and are therefore not limited to a narrow accounting definition of controls. This broad definition of control will become clear from the clarification of each lever, which follows below.

Simons' control model distinguishes four different types of control mechanisms:

1. Beliefs systems
2. Boundary systems
3. Diagnostic control systems
4. Interactive control systems

Two of these four levers increase individual freedom (i.e. beliefs systems and interactive control systems), and two restrict individual freedom (i.e. boundary systems and diagnostic control systems). The four levers are described below (Simons, 1995), and examples of each lever are given (Simons 1994):

- Beliefs systems are used to inspire and direct the search for new opportunities. A beliefs system is the explicit set of organisational definitions that senior managers communicate formally and reinforce systematically to provide basic values, purpose, and direction for the organisation. The definitions espouse the values and direction that managers want subordinates to adopt. These core values are linked to the business strategy of the firm. A formal beliefs system is created and communicated through such documents as credos, mission and visions statements, and statements of purpose.

- Boundary systems are used to set limits on opportunity-seeking behaviour. Boundary systems delineate the acceptable domain of activity for organisational participants. Unlike beliefs systems, boundary systems do not specify positive ideals. Instead, they establish limits, based on defined business risks, to opportunity seeking. Examples of boundary systems are the clear rules, limits and proscriptions in codes of business conduct, strategic planning systems, and capital budgeting systems.

- Diagnostic control systems are used to motivate, monitor, and reward achievement of specified goals. Diagnostic control systems are the formal information systems that managers use to monitor organisational outcomes and correct deviations from preset standards of performance. These feedback systems, which are the backbone of traditional management control, are designed to ensure predictable goal achievement. Three features distinguish diagnostic control systems: (1) the ability to measure the outputs of a process, (2) the existence of predetermined standards against which actual results can be compared, and (3) the ability to correct deviations from standards. Examples of diagnostic control systems are profit plans and budgets, goals and objectives systems, project monitoring systems, and brand revenue monitoring systems.

- Interactive control systems are used to stimulate organisational learning and the emergence of new ideas and strategies. Interactive control systems are formal communication systems that managers use to involve themselves regularly and personally in the decision activities of subordinates. Based on the unique strategic uncertainties they perceive, managers use these systems to activate search. Interactive control systems focus attention and force dialogue throughout the organisation. They provide frameworks, or agendas, for debate, and motivate information gathering outside of routine channels. These control systems stimulate search and learning, allowing new strategies to emerge as participants throughout the organisation respond to perceived opportunities and threats. An interactive control system is not a unique type of control system: many types of control systems can be used interactively, as long as they are important to the management, a regular agenda item during meetings, managers and subordinates meet and participate face-to-face about them, and assumptions are continually challenged.

The four different control levers in the model of Simons and their relation to strategy are summarised in table 3.1.

Table 3.1: Relating the four levers of control to strategy

Control system	Purpose	Communicates	Control of strategy as
Beliefs systems	Empower and expand search activity	Vision	Perspective
Boundary systems	Provide limits of freedom	Strategic domain	Competitive position
Diagnostic control systems	Coordinate and monitor the implementation of intended strategies	Plans and goals	Plan
Interactive control systems	Stimulate and guide emergent strategies	Strategic uncertainties	Pattern of actions

Source: Simons, 2000, p. 304

Any control system in an organisation can be classified according to the types that Simons (1995; 2000) distinguishes. The four different types of control systems work together to realise the business strategy. To be able to do this successfully, there should be a balance between, on the one hand, the strategy and the environment of the organisation and, on the other hand, the different types of control systems. If there is too much focus on just one or two types of control systems, the organisation will have difficulties in realising its strategy. However, putting equal emphasis on each of the four levers may also not be successful because the strategy and the environment in which the organisation operates may demand that one or more levers receive more attention than the others.

The right mix of control systems depends partly on environmental factors like the predictability and complexity of the market in which the organisation is operating. If the environment is predictable and not complex, an organisation can put more emphasis on the diagnostic control systems. However, if the environment is unpredictable and complex, a stronger focus on interactive control systems is necessary. Diagnostic control systems set order, and order needs predictability, therefore, these control systems are believed to be less effective in situations that are unpredictable and complex.

Studies that have empirically tested the four levers of control model tend to focus on this balance between diagnostic and interactive systems (see Ramos and Hidalgo, 2003; Bisbe and Otley, 2004), while the role of the beliefs and boundary systems in different organisational settings has hardly received research attention. The beliefs and boundary systems are both used to frame the strategic domain (Bisbe and Otley, 2004), because beliefs systems provide inspiration for emergent and intended strategies, while the boundary systems keep the realised strategies within the acceptable domain (Ramos and Hidalgo, 2003). We have not been able to find empirical research that explains to what extent the balance between beliefs and boundary systems is different for organisations that operate in different environments.

In terms of our research, the environment has become more complex and unpredictable for car manufacturers, because of increasing product variety and shortening product life cycles. Therefore, it is anticipated that the importance of interactive control systems has increased, and the importance of diagnostic control systems has decreased for the companies which we will study in this research.

3.6 Summary

This chapter has presented a review of management control literature, which has shown that management control and quality management have important similarities. The two disciplines of management control and quality management are historically related since they both have strong roots in the early scientific management thinking and in their pragmatic problem solving approach. The way management control and quality management currently operate is similar as well, because both pay explicit attention to performance standards which are used to measure and compare actual performance, and to correct any deviations from these standards.

However, there is also a major difference between management control and quality management. Research on management control has been contingency-based for a relatively long time, while research on quality management has been dominated by a universalistic approach.

The two studied trends of increasing product variety and shortening product life cycles are believed to change the environment in which organisations operate to such an extent that quality management systems need to adapt. Therefore, a model from the management control discipline has been used for the empirical part of this research. This model has been discussed, and the way in which it can deal with environmental contingencies has been explained.

The next chapter discusses how Simons' control model has been applied to the empirical research, and what hypotheses have been derived on the basis of the model.

4 Methodology

4.1 Introduction

The aim of this chapter is to describe the methodology of this research. The reasons for choosing the automotive industry are outlined and the risks of conducting research in this industry are discussed. The empirical research for this thesis consists of multiple case studies and a questionnaire survey. It is explained why this is a suitable approach given the aims of the research. Finally, the research model is clarified and application of this model by means of case studies is described in detail.

4.2 Empirical Research in the Automotive Industry

The empirical part of this research is based on case study research undertaken at three European automotive manufacturers and a questionnaire survey among a sample of European suppliers in the automotive industry.

As explained in chapter 1, the automotive industry is interesting for a number of reasons:

1. The automotive industry (e.g. Toyota) has been leading many other industry sectors in the application of quality management practices (e.g. Ohno, 1988; Shingo, 1989; Womack et al., 1990; Monden, 1998; Dale et al., 2000; Liker, 2004; Spear, 2004; Stallkamp, 2005).

2. Increasing product variety and shortening product life cycles are already clearly visible in the automotive industry (e.g. Pine, 1993; Womack et al., 1990; Alford et al., 2000; Agrawal et al., 2001; The Economist, 2001; Von Corswant and Fredriksson, 2002; The Economist, 2004; Sheffi and Rice, 2005). Car manufacturers now introduce new models on a frequent basis and the number of available options is increasing, although many features that, in the past, used to be options have now become standard equipment (De Saint-Seine, 2004). Life cycles of car models are under pressure because sales drop rapidly after a few years of production and even face-lifts can do little to counter this decline (Graham, 2005).

3. In an effort to retain as much as possible the operational benefits of mass production, many automotive manufacturers share platforms within brands and between brands of the same firm, or even with competing firms (Schlie and Yip, 2000). This indicates that manufacturers are trying to reduce complexity, and thereby reduce costs, by sticking to traditional mass production methods as much as possible, while on the other hand they try to offer customers the experience of a unique car (Stein, 2005; Meiners, 2005).

4. Current quality management systems are clearly under strain in the automotive industry since the number of product recalls has risen significantly (Simon, 2004). In the USA alone, product recalls in the automotive sector have risen from 208 in 1990 to 529 in 2003 (Aldred and Wernle, 2004), and the United Kingdom has witnessed a similar increase (Bates et al., 2004). To complicate matters, many of these recalls are not caused by internal problems at the car manufacturers but they arise from problems at their suppliers and even at sub-suppliers (Automotive News, 2002; Kisiel, 2003; Wernle, 2004; Stoffer, 2005).

Even though the automotive industry is unquestionably influenced by the two trends of increasing product variety and shortening product life cycles, care needs to be taken when undertaking empirical research. In general, there are two problems with choosing any single industry as the focus of study:

1. There will be other factors and developments that influence the way organisations manage quality.

2. In a large and diverse industry there will be organisations that are subject to extreme effects of increasing product variety and shortening product life cycles, but there will also be organisations that are not much influenced by these two trends.

Regarding the first problem, the automotive industry has been chosen because the influence of the two trends is strong in this industry. To accommodate for other influences on quality management, a multiple case study approach and a questionnaire survey among a broad sample of automotive companies have been chosen, which will help to single out the individual effects of increasing product variety and shortening product life cycles on quality management.

Regarding the second problem, it is anticipated to find different levels of product variety and different product life cycle lengths at different stages in the automotive supply chain. Although there is an enormous variety in the final product (i.e. the automobiles), some components may not be so diverse. For example, cars will vary in the quantity of nuts and bolts, and wires that have been used to assemble it, however, these components themselves may be quite similar between different cars (e.g. if one car contains twice the length of wires as another car, this does not necessarily mean that the wires themselves are different). Consequently, care needs to be taken in the empirical research when examining the way quality is managed in an organisation because organisations may differ in the extent to which they experience effects of the two studied trends

4.3 Research Objectives

This research is about the quality management discipline. Within this discipline the focus is on two trends (i.e. increasing product variety and shortening product life cycles) and their influence on quality management systems. This research should conclude about the extent and direction in which quality management systems are changing in order to cope with an environment of increasing product variety and shortening product life cycles. Therefore, this research has two objectives. The first objective is to understand the influence of increasing product variety and shortening product life cycles on companies, and on the way they manage and improve quality. The second objective is to assess the extent and direction in which quality management systems are changing in situations of increasing product variety and shortening product life cycles. These research objectives are in line with the problem definition and research questions, which were presented in chapter 1. The problem definition of this research is:

> *How do increasing product variety and shortening product life cycles influence quality management of firms and what is the consequence of this for quality management systems?*

The research questions are:

1. How do increasing product variety and shortening product life cycles affect firms?

2. How do increasing product variety and shortening product life cycles influence quality management of firms?

3. To what extent are quality management systems changing in order to be capable of coping with increasing product variety and shortening product life cycles?

As argued in chapter 2, quality management is based on the assumptions of large batches of the same or similar products that are repeated over time. Quality management aims at avoiding variation in organisational processes (Wilkinson et al., 1998; Dean and Bowen, 1994; Handfield and Melnyk, 1998) and it is looking for small, incremental improvements (or kaizen) (Imai, 1986; Bryce, 1991). The two trends of increasing product variety and shortening product life cycles challenge these assumptions because they have the potential to cause large variations in organisational processes. That is the reason why this research aims to assess the effects of the two trends on quality management, given the challenged assumptions.

4.4 Research Design

As described in the previous section, this research has two objectives. According to Robson's (2002) classification of the purposes of enquiry, the first objective is exploratory in the sense that it tries to find out what the influence is of increasing product variety and shortening product life cycles on the management and improvement of quality by companies. The second objective is explanatory (Robson, 2002) since it is focused on explaining in what way quality management strategies and practices may adapt in order to cope with situations of increasing product variety and shortening product life cycles.

The necessary empirical data about increasing product variety and shortening product life cycles will be collected by means of a number of case studies and a questionnaire survey. The reason for choosing both a case study approach, as well as a questionnaire approach, is their suitability for achieving the two research objectives. Case studies are most appropriate for exploratory research, while questionnaire surveys are most appropriate for explanatory research (Robson, 2002; Yin, 2003).

4.4.1 Case Studies

Three case studies at European automotive companies have been undertaken. The aim was to find multiple case companies that were expected to have been influenced to different extents by the two trends of increasing product variety and shortening product life cycles. Later on, in table 4.2, the expected influence of the two trends on each of the case companies will be explained. Given the expectation that the three case companies cover the full scales (low, medium, high) of both product variety and product life cycles (see table 4.2), it was decided to limit the research to three cases.

Some basic information about the case companies is presented in table 4.1. The second row in the table describes the type of production that takes place at each of the case companies. Heavy Truck Co has brand responsibility for the trucks it assembles, which means that it not only assembles the trucks but it also develops and sells them. Small Car Co does contract manufacturing, which means that it is only responsible for assembling the cars, and not for development and marketing activities. Premium Car Co is a production location, which has a similar profile as Small Car Co, however, it is part of a larger hierarchical organisation. Small Car Co needs to make a profit on its assembly activities in order to survive, while

Premium Car Co is not judged on profit because it is a cost centre within the larger organisation to which it belongs.

In the following three chapters (5, 6 and 7) the results of each of the case studies will be presented and examined, and in chapter 8 a comparative analysis of all three cases is undertaken.

Table 4.1: Characteristics of the studied case companies

	Case company 1 Heavy Truck Co (Chapter 5)	Case company 2 Small Car Co (Chapter 6)	Case company 3 Premium Car Co (Chapter 7)
Market segment	Heavy trucks	Small cars	Lower premium cars
Type of production	Brand responsibility	Contract manufacturing	Production location
Annual production volume	45,000	210,000[1]	80,000
Number of different models assembled	2	2	1
Number of employees	3,500	4,300[2]	2,000
Factory location	Western Europe	Western Europe	Western Europe
Number of first tier suppliers	440	250	220
Major suppliers on-site in supplier park	No	Yes	Yes

1: Has been reduced during the years 2004 and 2005 to 115,000 cars
2: Has been reduced during the years 2004 and 2005 to 3,000 employees

These case studies are meant to provide a better understanding of the factors that are important in this research. The case studies focus on the 'how' and 'why' of changes in quality management systems as a result of trends in product variety and product life cycles. According to Yin (2003), case studies are particularly suitable for answering 'how' and 'why' questions.

To be able to answer the research questions, the case studies should be conducted both in situations where there is little influence of increasing product variety and shortening product life cycles and in situations where there is a strong influence of these trends. Therefore, contrasting firms or business sectors, or firms at different moments in time need to be studied (Yin, 2003). According to Yin (2003), each case should be selected so that it either predicts similar results as another case (a literal replication), or contrary results but for predictable reasons (a theoretical replication).

To determine the extent to which increasing product variety and shortening product life cycles are an issue in different business sectors, a number of interviews have been conducted at the start of this research project. These interviews were conducted with managers from different firms across various business sectors in The Netherlands (see appendix 4.1). From these interviews it has been concluded that the automotive industry is very interesting to conduct the case studies, since increasing product variety and shortening product life cycles are a major issue in this industry. A literature review confirms that the automotive industry is highly influenced by increasing product variety and shortening product life cycles (see section 4.2).

To contrast these cases of increased product variety and shortened product life cycles with situations in which there is little influence of these two trends, the history of the same automotive companies has been studied. During interviews with managers at the automotive companies, these managers have been asked to contrast the current situation at their companies with the situation that existed ten years ago. If managers have not been working for their current employer for a long time, they are asked about their perceptions about the situation that existed ten years ago. The ten years time frame has been chosen because car manufacturers deal with products that have, in absolute terms, still a long life cycle and many changes and improvements are only possible with the introduction of a new car model. So, a time frame of, for example, five years would be too short to see significant changes. During a ten year time frame, it is very likely that a car model change has taken place, and by comparing the situation that existed during the production of the previous car model with the situation during the current model, much can be learnt about how quality management systems have changed at a car manufacturer. Another reason for choosing the ten years time frame is the fact that it has been used before in empirical studies by Pine (1993) and by Von Corswant and Fredriksson (2002). When conducting the interviews, the ten years time frame turned out to be no problem at all because all interviewed managers have been working for a relatively long period of time for their current employer (even up to forty years). Moreover, the explanations of the individual managers about what has happened over time were consistent with each other, even when it concerned details of the more distant past (i.e. more than ten years ago).

This type of research is a cross-sectional multiple case study approach, although it contains aspects from a longitudinal case study approach as well, because it involves two moments in time of the same cases (Yin, 2003). The reason to conduct this form of case study is to limit unwanted influences by other variables (e.g. business sector, market saturation and quality of labour). Another possibility would be to conduct case studies in contrasting business sectors but then it would not be clear if the findings were the result of the two studied trends or of the fact that the case companies are simply different because they operate in different business sectors. It will be very difficult to control for these unwanted influences, unless the case studies are conducted in the same business sector. Therefore, this research has studied one business sector and focussed on the present (when product variety is relatively high and product life cycles are relatively short) and the past (when product variety was relatively low and product life cycles were relatively long). Proceeding in this way, it will be possible to attribute the differences found to increasing product variety and shortening product life cycles.

Although two moments in time have been studied, the interviews have not taken place at two different time periods. Each manager has been interviewed once (some were in fact interviewed two or three times, but only to gather additional information or discuss findings), and during the interview he or she has been asked to describe how the business is managed today and compare that to ten years ago. This leads to conclusions about shifts over time.

The three cases have been selected because of their differences. Even though it was anticipated that all three have been influenced by increasing product variety and shortening product life cycles, it was also expected that they have been influenced in different ways and to different extents. The influence on a heavy truck manufacturer was believed to differ from the influence on a small car manufacturer, which was in turn thought to be different from the influence on a premium car manufacturer.

Table 4.2 compares the anticipated influence of product variety and life cycle trends for each of the companies. Product variety was expected to increase only slightly for the heavy truck manufacturer because trucks have traditionally been vehicles that have to suit very diverse commercial needs. However, many (electronic) driver aids have been introduced in the last couple of years. The length of product life cycles was also expected to become only slightly shorter for heavy trucks. Trucks are bought because of rational commercial needs and not so much for fun or luxury reasons. However, rapid advances in technology have continuously reduced fuel consumption and pollution by trucks. This necessitates manufacturers to develop new trucks which contain the latest technology.

The manufacturer of small cars was expected to increase product variety quite a bit over the ten year period, but not to the extent of the premium car manufacturer. The prices of small cars are relatively low and therefore product variety was expected to remain limited. The prices of premium cars are much higher though, and their customers are very demanding. For upper premium cars (i.e. the ultra luxury cars), customers are so demanding that they expect many options and high-tech gadgets to be standard equipment. Lower premium cars (i.e. the volume car models of premium car brands) have less standard equipment. So, it was expected that there would be massive variety in lower premium cars because these have long option lists. Consequently, for the case studies a company has been selected that manufactures cars for the lower premium segment.

The small cars segment has become very volatile and brand loyalty has diminished. So, it was expected that existing car models need to be updated frequently and new car models need to be developed rapidly to attract customers and maintain high sales levels. Buyers of premium cars are more loyal to their brand than buyers of small cars. Therefore, manufacturers of premium cars were expected to have fewer incentives to constantly introduce new car models.

Table 4.2: Anticipated influence of product variety and life cycle trends

	Case company 1 Heavy Truck Co (Chapter 5)	Case company 2 Small Car Co (Chapter 6)	Case company 3 Premium Car Co (Chapter 7)
Expected influence of product variety	*Low:* Trucks have for many years been tailored to commercial needs of customers. So, this may have changed relatively little over the last couple of years.	*Medium:* Small cars come in more varieties than they used to, but in fewer varieties than larger cars.	*High:* Premium car makers try more than ever to fulfil all possible wishes of their demanding customers.
Expected influence of product life cycles	*Low:* Trucks have long life cycles, although they currently seem to get shorter than in the past.	*High:* The small cars segment has become very volatile and brand loyalty has diminished. So, cars need to be updated frequently to maintain high sales levels.	*Medium:* Buyers of premium cars are more loyal than buyers of other kinds of cars. This reduces the need to constantly introduce new car models.

Despite the anticipated developments at each of the case study companies, care needs to be taken when doing case study research because it is demanding in the sense that it is time consuming and it requires skilled interviewers (Voss et al., 2002; Easterby-Smith et al., 2002). On the other hand, the lack of restrictions of the case study approach can lead to creative results with high impact (Meredith, 1998; Voss et al., 2002).

The results of the three case studies will be compared and conclusions drawn about the trends in product variety and product life cycles on the basis of an analytic generalisation. This type of generalisation treats each case study as an experiment of its own, instead of statistical generalisation that would treat each case study as a data point in a study (Yin, 2003).

An advantage of studying the automotive industry is that there are a lot of data available from research institutes in the automotive sector (e.g. Automotive News and Automotive News Europe, the Japan Automobile Manufacturers Association, the German Kraftfahrt Bundesamt, America's eAuto Portal, PriceWaterhouseCoopers' Autofacts, and McKinsey's Automotive and Assembly). Automotive News has been reporting on all important automotive industry developments since 1925 and it is regarded as a major trade paper in quality management literature (Cole, 1999). These data sources have been used extensively during the research, both as frame of reference and as direct sources of specific information.

4.4.2 Questionnaire Survey

The results of the case studies will be used to develop a questionnaire survey aimed at a much larger number of supplier firms in the automotive industry. This questionnaire survey will generate quantitative data, so statistical analyses can be conducted and the effects can be quantified. The questionnaire survey will focus on the 'what', 'how many' and 'how much' of changes in quality management as a result of trends in product variety and product life cycles. These kinds of questions are best studied by means of a questionnaire survey (Yin, 2003).

The questionnaire survey will be cross sectional. However, it will be designed in such a way that the current situation is compared to the situation that existed at car manufacturers ten years ago. So, the structure of the questionnaire will follow a similar pattern as the case studies. The complete design and structure of the questionnaire will be dependent on the outcomes of the case studies and will therefore be discussed after the results of the case studies (i.e. in chapter 9).

4.5 Research Model

In this section the model that has been utilised for the empirical part of the research is described. On the basis of this research model, some hypotheses are then derived, which will be tested in the empirical part of the research. The section concludes with a description of the way in which the research model has been applied to the three case studies.

4.5.1 Simons' Four Levers of Control Model

For the case studies and the questionnaire survey to be meaningful and effective, they should be built upon a suitable research model (Lee, 1989). The model that has been chosen for this research is Simons' four levers of control model (Simons, 1995), which is presented in figure 4.1. The reasons for choosing this research model have been discussed in chapters 2 and 3 of this dissertation. To summarise, a model is needed that can distinguish between, on the one hand, simple and stable environments and, on the other hand, complex and unpredictable environments. A detailed explanation of the meaning and contents of the research model can be found in chapter 3.

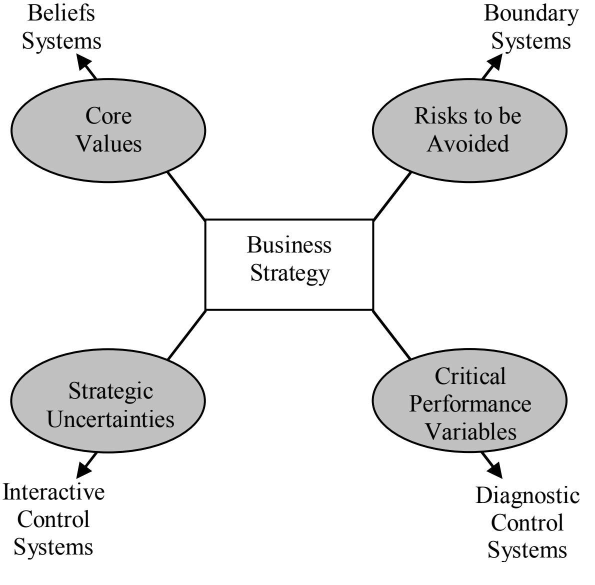


Figure 4.1: Simons' four levers of control model (Simons, 1995)

This research utilises Simons' four levers of control model to assess the effects of increasing product variety and shortening product life cycles on quality management of firms. This research is not meant to test the Simons model itself.

The use of Simons' four levers of control model in an interview setting has been practiced both before and during the case studies. Three managers in different organisations, across several business sectors agreed to participate in a try-out interview (see appendix 4.2). These try-out interviews led to improvements of the interview approach for the case studies.

4.5.2 Hypotheses on the Basis of the Research Model

As explained in chapter 3, the control model of Simons has been chosen as research model because it can cover, on the one hand, simple and stable environments and, on the other hand, complex and unpredictable environments. According to the model, these types of environments require a different set of control systems. Managers in organisations that operate in simple and stable environments can focus mainly on the diagnostic type of control systems, whereas managers in organisations that operate in complex and unpredictable environments will have to make more use of the interactive type of control systems (see chapter 3).

As argued in chapter 1, increasing product variety and shortening product life cycles both mean that the environment becomes more complex and unpredictable. Therefore, the extent to which an organisation is influenced by increasing product variety and shortening product life cycles is expected to be reflected in the extent to which the organisation makes use of the different types of control systems.

On the basis of the research model, in combination with the anticipated influence of product variety and product life cycle trends on the case companies (see table 4.2), a number of hypotheses can be formulated. The hypothesised effects on quality management systems for the case companies are presented in table 4.3.

Table 4.3: Hypotheses about quality management systems for the cases

Case company	Hypotheses
Heavy Truck Co	Quality management is mainly focused on diagnostic systems.
Small Car Co	The quality management focus has shifted towards interactive systems.
Premium Car Co	The quality management focus has shifted towards interactive systems.

The hypotheses for the questionnaire survey are in line with the case hypotheses. So, organisations that have witnessed an increase in product variety or a decrease in product life cycle length are expected to have concentrated more on interactive quality management systems, while organisations that have not witnessed an increase in product variety or a decrease in product life cycle length are expected to focus mainly on diagnostic quality management systems.

4.5.3 Application of the Research Model to the Cases

The following chapters (5 to 8) will discuss and analyse the case studies. Therefore, this section explains how Simons' model has been applied to these case studies. The application of Simons' model to the questionnaire survey will be discussed in chapter 9.

As explained before, the case studies are meant to explore the effects of increasing product variety and shortening product life cycles on quality management. Therefore, the case study approach is not very rigidly structured. Instead, most information about the case companies has been collected by means of semi-structured interviews. These semi-structured interviews help, on the one hand, to adhere to the research model and objectives, while on the other hand they allow for unanticipated issues to emerge during the interviews (Yin, 2003).

In all three case companies, interviews have been held with the quality manager, supply chain manager, production manager, and human resources manager (for Small Car Co, the logistics manager has been interviewed as well). In addition, three relevant first tier suppliers have been selected by the quality managers of each of the case companies (for Premium Car Co, only two suppliers could be interviewed). The quality managers selected suppliers that are important in terms of the components they supply, and in terms of the influence these components have on the final product. At each of the suppliers, interviews have been held with the quality manager (sometimes together with the account manager for the case company). The reason for interviewing supplier firms is the significant increase in outsourcing and the resulting influence that suppliers have on the final product. In 2006, supplies account for about 65 percent of the costs of a car and this is expected to rise to about 75 percent in the near future (De Saint-Seine, 2006). Therefore, the views of suppliers on the outsourcing practices and supply chain management of each of the case companies are an important contribution to the case research.

All interviews have been conducted by two interviewers (i.e. Jos van Iwaarden MSc. and Dr. Ir. Ton van der Wiele, both from Erasmus University Rotterdam, The Netherlands) and each interview has taken between one and a half and three hours. The interviews inside the case company have all focused on the changes in management systems that have taken place over the last ten years in the field of responsibility of the interviewee. Where possible, expectations for the future were discussed as well. The interviews at the suppliers have been focused on the changes that have taken place in the way the relationship between the supplier and the case company is managed by the case company.

Six stages have been involved in the interviewing process:

1. The interview itself. Both interviewers have, individually, written down each interview.

2. Discussion between the two interviewers. Any discrepancies between the two write-ups were resolved through discussions. Based on the two write-ups and the discussions, an accurate write-up of the interview has been produced.

3. Request for comments from interviewee. The write-up of the interview was sent to the interviewee with a request to comment on it and correct any errors. All feedback from the interviewees has been incorporated in the final write-ups.

4. Discussions with quality experts. Out of the final write-ups the most important quality management issues and developments have been derived by means of discussions between the two interviewers and two academic quality experts (i.e Prof. Dr. Barrie Dale from the Manchester Business School, UK and Prof. Dr. Roger Williams from Erasmus University Rotterdam, The Netherlands).

5. Feedback sessions. The derived quality management issues and developments have been presented to the interviewees in a discussion meeting during which these managers could express their perceptions and opinions.

6. Final version of quality management issues and developments. The feedback from the interviewees has been incorporated in the final overview of derived quality management issues and developments.

In addition to the interviews at the case companies and their suppliers, information has been collected by means of plant tours and by studying minutes of relevant meetings and quality management procedures and policies.

Each of the three case studies has become an in-depth case study. Eventually, this has resulted in a substantial amount of collected data. The interview write-ups alone cover more than 150 pages A4, and these data therefore provide a good basis for analyses.

Simons' four levers of control model is used in the following way for each of the three cases:

- On the basis of Simons' model and the literature review about the automotive industry, a list of questions has been developed for each of the fields of responsibility (i.e. the quality manager, the supply chain manager, the logistics manager, the production manager, the human resources manager, and the quality manager at the first tier suppliers). These lists of questions are presented in appendix 4.3. Since the interviews were semi-structured, the lists of questions were guidelines for the discussion and were not meant to be answered in a restricted and linear way.

- The interviews have focused as much as possible on specific examples of developments and changes that have taken place over time in the field of responsibility of the interviewee as a result of shifts in product variety and product life cycles. Based on these developments, the effects on quality management at a case company have been analysed. The systems that have been used at any moment in time by the case company to manage quality have been positioned in the four quadrants of Simons' model (i.e. beliefs systems, boundary systems, diagnostic control systems, and interactive control systems) by assessing the focus of each of these systems. Some elements of the quality management system may fit more than one quadrant of Simons' model, however, the interviewers have grouped them on the basis of their major focus, which is based on discussions with the two academic quality experts and the managers of the case company.

- Some of the quality management systems are related to each other, in the sense that they aim to manage the same business aspect but at different moments in time. These quality management systems have been connected to each other by means of arrows, in order to indicate that the emphasis has shifted over time from one system to the other. By doing so, trends emerge that indicate which levers of Simons' control model were important at different moments in time.

- Possible future trends have been identified as well, based on the current developments and the interviewees' expectations about developments that are planned for the near future.

4.6 Research Framework

To summarise the methodology of this research, which is described in the previous sections, a visualisation of the research methodology is presented in figure 4.2. In the left part of the figure the theoretical knowledge is shown. Based on this knowledge the case studies will be conducted. These case studies will be used to draw conclusions and to develop a questionnaire. Finally, conclusions will be drawn on the basis of both the results from the case studies and those from the questionnaire survey.

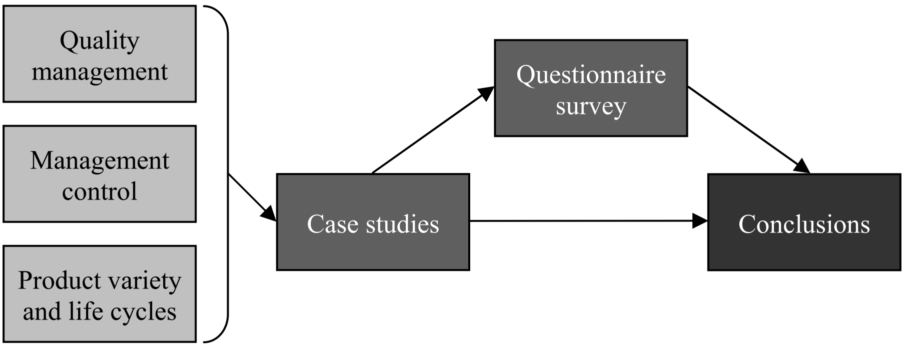


Figure 4.2: Graphical representation of the methodology of the research

4.7 Type of Research

This research project has utilised both qualitative and quantitative methods, i.e. a mixed methods approach has been used (Creswell, 1994). The case studies have generated qualitative data from three car manufacturers. The questionnaire survey will result in quantitative data from a much larger number of automotive supplier companies.

The combination of both qualitative and quantitative research (triangulation) increases the robustness of this research as opposed to just using either qualitative or quantitative research (Patton, 2001). Other types of research design would of course also be possible but they would make it more difficult to draw conclusions about the research problem statement. One could choose to do a very detailed case study of a single firm. This would lead to detailed information about the effects of increasing product variety and shortening product life cycles on quality management in that specific firm. Whilst this type of research is probably very useful for the researched firm, it is very difficult to draw general conclusions from the findings of a single case study. One could also choose to conduct a questionnaire survey only. This would help to quantify the effects. However, it is at this moment not at all clear what this questionnaire survey should look like because the exact nature of increasing product variety and shortening product life cycles and their effects on quality management are not yet clear.

4.8 Summary

In this chapter the research methodology has been explained. It has been shown that the automotive industry is an interesting industry to conduct the empirical part of this research. Both from the literature and from an initial round of interviews, it has been concluded that the automotive industry is highly influenced by increasing product variety and shortening product life cycles.

It has been explained that this research has two objectives. The first objective is to understand the influence of increasing product variety and shortening product life cycles on companies, and on the way they manage and improve quality. The second objective is to assess the extent and direction in which quality management systems are changing to cope with an environment of increasing product variety and shortening product life cycles. The first objective is exploratory and therefore very suitable for case studies, while the second objective is explanatory and therefore suitable for a questionnaire survey. Consequently, the empirical part of this research consists of both case studies and a questionnaire survey.

The case studies and the questionnaire survey are both built upon Simons' four levers of control model. The application of this model to the case studies has been described in detail.

The following three chapters (5 to 7) will present each of the three case studies in the order they have been undertaken. Studying the cases has been a learning process, which means that the first case study has been the most challenging, while the other two could benefit from the skills learned during the first case.

5 Case Study 1: Heavy Truck Co

5.1 Introduction

This chapter describes case company 1, which has been named Heavy Truck Co. The general characteristics of Heavy Truck Co are presented in table 5.1. Heavy Truck Co is a manufacturer of heavy trucks for the transportation industry. Until the 1980s, the company had had a long history as a successful independent truck manufacturer. However, by the end of the 1980s, the situation of Heavy Truck Co deteriorated for various reasons. The most important of these being, providing credit to customers who were unable to get money from other sources (like banks), which increased the financial risks for Heavy Truck Co substantially, and, secondly, applying a build-to-plan strategy, which clogged the sales channels with 10,000 trucks that still had to be sold to a customer. As a consequence of this, Heavy Truck Co went bankrupt in the early 1990s and was acquired by another manufacturer of heavy trucks. Since then, Heavy Truck Co has again been a profitable truck builder with a growing market share. Even though Heavy Truck Co is now part of a large group, it still assembles and sells trucks under its own brand name. Heavy Truck Co is completely responsible for this truck brand, from design and engineering to sales and customer service. The brand currently consists of two types of heavy trucks. The interviewed managers were able to tell a lot about the developments at their organisation because they have had a long history with Heavy Truck Co. On average, they have been working at Heavy Truck Co for about thirty years.

The methodology of the research has been described in detail in chapter 4. Therefore, this chapter only describes the data that have been collected from the case company by means of interviews, document study, factory tours and feedback meetings. Table 5.2 provides an overview of all interviews and factory tours that have taken place at Heavy Truck Co and its suppliers. During the interviews, the managers of Heavy Truck Co and its suppliers have presented their views and opinions, however, whenever possible these views have been supported by relevant facts. Moreover, the data about Heavy Truck Co reported in this chapter are not just the quality manager's views, because all issues presented have been raised by at least two Heavy Truck Co managers. In addition, factory tours and document studies have been used to support the information from the interviews. These forms of cross examination (i.e. triangulation) of the case study are intended to improve the reliability of the results. Direct quotes from the interviewees are used throughout the text to support the statements made. If an interview has been conducted in another language than English, the presented quotes are a translation of the original quotes, agreed with a native English speaker who is also fluent in the language of the interview.

Following the introduction, the relevance of the case company in relation to the topic and aims of this research is explained. The data from the case company are then presented to explain what relevant developments have taken place at the case company over the last ten years. These data are structured along the three building blocks of quality management (i.e. customer focus, reduction of variation in organisational processes, and continuous improvement), which have been explained and discussed in chapter 2. Where relevant, references to available literature are made in the case study data. Following the examination of the case company, an examination of three of its first tier suppliers is presented. In the final section of this chapter the findings from the entire case study are discussed and interpreted.

The data description only contains relevant facts from the case study company and no comparative analysis with the other case companies is undertaken at this stage of the research (the analysis of all three cases is presented in chapter 8). The data are also not interpreted in terms of Simons' four levers of control model, since this will also be dealt with in chapter 8.

Table 5.1: Characteristics of Heavy Truck Co

	Heavy Truck Co
Market segment	Heavy trucks
Type of production	Brand responsibility
Annual production volume	45,000
Number of different models assembled	2
Number of employees	3,500
Factory location	Western Europe
Number of first tier suppliers	440
Major suppliers on-site in supplier park	No

Table 5.2: Interviews at Heavy Truck Co and its suppliers

Company	Interviewee(s) / *Activity*	Date
Heavy Truck Co	Quality manager	10 November 2003
Heavy Truck Co	Quality manager	14 January 2004
Heavy Truck Co	Supply chain manager	19 February 2004
Heavy Truck Co	Human resources manager	15 March 2004
Heavy Truck Co	Production manager	15 March 2004
Heavy Truck Co	*Plant tour*	15 March 2004
Heavy Truck Co	Quality manager	19 May 2004
Heavy Truck Co	Quality manager; Supply chain manager; Human resources manager	7 July 2004
Supplier 1	Quality manager	28 May 2004
Supplier 2	Quality manager; Sales manager	2 June 2004
Supplier 2	*Plant tour*	2 June 2004
Supplier 3	Sales manager	3 June 2004

5.2 Relevance of Heavy Truck Co for the Research

In this section the research context of Heavy Truck Co is described. The extent to which increasing product variety and shortening product life cycles play a role for Heavy Truck Co is discussed first. Thereafter, the importance of quality management for Heavy Truck Co is explained.

5.2.1 Product Variety and Life Cycles

Over the last decade, product variety has increased at Heavy Truck Co. However, the management of Heavy Truck Co emphasised that there has been a large variety of products for a longer time because they have been building trucks to the specifications of the individual customer for many years. A development of the last couple of years has been that more buyers of heavy trucks actually select many of the available options. Ten years ago, buyers could choose for a customised truck but they quite often would buy one that was quite standard. The quality manager said:

> *"Nearly any truck that is built these days is different from the others. That is more than in the past, so more trucks are tailored to the customer's needs these days."*

So, even though the potential product variety (i.e. the number of possible product variants) has not increased very much over the last decade, the actual variety on the assembly line has.

Developments in terms of product life cycles are also playing a role at Heavy Truck Co. The management explained that product life cycles of heavy trucks have become shorter over the last decade. However, the reasons for this are not found in the area of design or offering the latest technologies, but in regulatory changes (e.g. changing emission and safety norms). To comply with stricter regulations, Heavy Truck Co has to speed up new product development. The quality manager explained:

> *"Our customers are companies and lease organisations, and these judge the trucks by their operational economics and safety and not so much by aesthetic features or new gadgets."*

So, product life cycles are under tension at Heavy Truck Co but for reasons that are to a large extent not driven by customer demands.

An example that indicates that the trends of shortening product life cycles and increasing product variety are relevant for Heavy Truck Co, is found in the engine assembly department. The engines blocks have a long life cycle (about fifteen years) but the complete engine has a much shorter life cycle (only a couple of years). So, the same engine block is used for many years, but the modules and parts that are attached to it change on a regular basis. Nowadays these modules and parts change more frequently than they did ten years ago. Customers can choose various optional parts and modules for their engines (e.g. special pumps, one or two air conditioners, the number of gears in the gearbox, etc.), which leads to variety in the final products. As argued before, today's customers are more likely to choose these optional parts than the customers of a decade ago.

The increased variety on the assembly line has consequences for the employees in the plant. The human resources manager explained:

> *"There are no two trucks that are the same anymore, so complexity has increased. Employees need to stay alert while doing their job because they have to think what tasks they have to do on a truck that moves down the production line."*

The interviewed managers were agreed that in the future the focus at Heavy Truck Co will be more on people than on technology. Work at Heavy Truck Co's production line is a combination of relatively low-skill work and a large variety of different products. The large variety of products means that employees may forget certain tasks, or perform unnecessary or wrong tasks. It also demands that each production cell (i.e. group of employees on the shop floor) has a leader who has a lot of knowledge about all possible tasks and all possible truck variants that have to be worked on.

5.2.2 Importance of Quality Management

The interviewed managers were in agreement that over the last decade the management and improvement of quality has become much more important for Heavy Truck Co. The managers of Heavy Truck Co were convinced that this was mainly caused by the concrete results that have been achieved during this period by means of improvement projects based on Six Sigma (see for example Bhote and Bhote, 1991; Pande et al., 2000; Pyzdek, 2003) and Kaizen (see Imai, 1986; 1997). The quality manager explained:

> *"Nowadays, there is much more top management interest in quality, and problem solving has evolved from a non-scientific trial-and-error approach to a more scientific systems approach that is based on facts."*

The quality manager explained how in the past most improvement projects would start with a statement from an employee, who said that he or she thought that something might be improved. Nowadays, an improvement project will only start if and when there is clear evidence about what is wrong and how much will be saved if it is fixed.

The success over the last ten years of the quality projects within Heavy Truck Co made it much easier to get money for these projects from the owner of Heavy Truck Co. The quality manager told:

> *"Sometimes they were so readily available to provide extra money for improvement projects, that it surprised us."*

An example of this is a new engine project at Heavy Truck Co. When a new engine production line was to be installed, Heavy Truck Co immediately saw the opportunity to turn this into a Six Sigma project. Heavy Truck Co wanted to increase the process capabilities of this process because that would mean that the process variance would stay more easily within the lower and upper specification boundaries that Heavy Truck Co had formulated for this process. Therefore, Heavy Truck Co suggested increasing the CPk value from the current level of 1, to a CPk value of 2 for the new engine production line. However, to reach the higher CPk value, better equipment had to be bought than what was planned beforehand. Consequently, Heavy Truck Co sent a request to Heavy Truck Co's owner for 30 million Euros instead of the planned 25 million. Within a couple of weeks Heavy Truck Co's owner approved the additional investment. All managers were agreed that before the success of Heavy Truck Co's quality projects, Heavy Truck Co's owner would never provide extra funds so readily.

These examples show that the quality department of Heavy Truck Co is highly respected within the organisation because of the successes it has had. Another indicator of its success is the fact that the quality department has been one of the few departments that has grown in employee numbers over the last couple of years. The clearest indication for Heavy Truck Co's managers that they are doing better than the other brands of Heavy Truck Co's owner, is the recognition they have received from the owner of Heavy Truck Co. The quality manager told:

> *"We have won an award for our highly successful systematic approach to problem solving and improvement, and we*

received an award because we had the best score at the last quality audits."

All these successes over the last couple of years do not mean to Heavy Truck Co's management that there is nothing left to improve for the future. Several important developments in the area of quality management were indicated by the management team:

- Firstly, quality assurance at Heavy Truck Co has evolved over time via a number of stages. During the 1970s and 1980s, Heavy Truck Co tried to achieve quality assurance by means of formal quality systems like AQAP (see Dale, 2003) and ISO 9000 (see ISO, 2000; ISO, 2005; Van der Wiele et al., 2005). In the last decade, Heavy Truck Co has tried to assure the quality of its trucks by reducing dependability on people (e.g. through the use of scans and robots). More recently, Heavy Truck Co has realised that people are crucial for quality assurance and therefore they are now much more involved. The importance of teams for quality assurance efforts has increased, and teams are also held responsible for their quality performance.

- Secondly, outsourcing has increased significantly over the last couple of years. In 2004, 80% of a truck is purchased from suppliers. Heavy Truck Co builds its trucks with the goal that they should have a technical life span of at least 1.6 million kilometres. Taking into account that 80% of the parts of these trucks are built by suppliers, these suppliers play a crucial role in ensuring the desired lifetime of the truck. Heavy Truck Co has learnt in recent years that an increase of outsourcing means that many quality problems with the trucks are a consequence of parts that have been bought in from suppliers. Quality problems of this type are much harder to solve for Heavy Truck Co than problems that are caused by Heavy Truck Co itself. The management has experienced that in many cases the problems already start at Heavy Truck Co's second and even third tier suppliers. Although Heavy Truck Co has reduced the number of its first tier suppliers, the number of second and third tier suppliers has increased significantly over the last couple of years. Therefore, management of the supply chain has become much more important for Heavy Truck Co, and will continue to do so in the future.

- Thirdly, there is still room for quality improvements in terms of enhancing the comfort and appeal of the trucks. Heavy trucks have traditionally been looked at from a very rational and operational point of view. Trucks are used for business purposes and should therefore primarily be able to fulfil the tasks they were developed for. Today, this is still the case but Heavy Truck Co's management feels that truck builders should also pay attention to the comfort of the truck driver. By designing the cab of the truck from the truck driver's point of view, Heavy Truck Co has been able to realise important improvements. An example is the bed inside the cab of the truck, which has been improved so well that many long-haul truck drivers are willing to sleep in their cab instead of in a hotel, thus saving money. The production manager feels that a truck should be built to the same quality standards as a passenger car.

- Fourthly, an issue that will increase in importance for Heavy Truck Co in the near future, is the issue of production for recycling. The idea behind this development is that quality should not be higher than necessary. So, in the case of a door handle, an iron version may last longer than a plastic version but if the plastic version is working fine until the truck is put out of service then there is no need to use the iron version. In that case there will be a stimulus to use the plastic door handle if that version is easier to recycle. The need to pay more attention to recycling of the trucks is the result of government regulations that force manufacturers to take care of truck disposal in an environmentally friendly way.

This list of quality management issues shows that the management and improvement of quality is a top priority for Heavy Truck Co.

5.3 Customer Focus

In this section Heavy Truck Co's focus on the customer is discussed. The most relevant issue for Heavy Truck Co are the expectations of its customers (i.e. what do customers expect from their new trucks?). This issue is dealt with in the remainder of this section.

5.3.1 Customer Expectations

The first three years after the take-over, Heavy Truck Co was very much internally focused. The new owner of Heavy Truck Co managed the organisation in a hierarchical and costs-focused way. During this time, Heavy Truck Co basically had to please two customers: the normal customer and Heavy Truck Co's owner. Before the take-over, Heavy Truck Co's management maintained strong external relations with its customers. The management knew all the dealerships and also quite a few of the larger customers. After the take-over, a lower organisational level (i.e. the marketing and sales department) became responsible for the external relations. This, however, led to a slower response by Heavy Truck Co to external developments in the market place.

In the second half of the 1990s, the external relations have again become a priority for top management at Heavy Truck Co. As a consequence of this, Heavy Truck Co has become better able to pick up signals from the market place. An example of this is the renewed focus on operational economics and safety as key quality issues. The previous internal focus of Heavy Truck Co had led to the belief that delivery quality (i.e. the quality of the truck at the moment of delivery to the customer) was the most important quality issue for customers. However, when Heavy Truck Co started improving its external relations, it learned that operational economics and safety during the life span of the truck were rated as most critical by customers. The quality manager talked about a truck of another brand of Heavy Truck Co's owner:

> *"This truck was filled with one million dollars worth of salmon when it broke down in the middle of nowhere. The cooling systems stopped working and before the truck was repaired the salmon had already gone bad."*

This explains why customers rate operational economics so highly. The issue of warranty plays an important role in relation to the operational quality aspects. If the operational quality increases, the costs of warranty issues will decrease for Heavy Truck Co. Moreover, if the operational quality increases, the customers are also more likely to be happy with their trucks. Therefore, by improving operational quality, Heavy Truck Co aims to reduce its costs and improve customer satisfaction. To be able to improve operational economics and safety, Heavy Truck Co needs to know a lot about how the end user operates the truck. The management of Heavy Truck Co thinks that it does not have enough data at the moment about the end users and their perceptions. Therefore, in the near future data about lost sales and repetitive sales will be collected by Heavy Truck Co. Another way in which information about operational economics and safety reaches Heavy Truck Co is by recording customer complaints. The management has little doubt that operational economics and safety can be improved, because customer surveys consistently point in that direction.

An issue about which customer surveys are less consistent, is the reason why Heavy Truck Co has been growing in market share over the last five years. Heavy Truck Co's market share in Europe has grown by nearly four percentage points over a five year period, to more than 10%. This is a good performance, especially when taking into account that during some years the total market shrank. The quality manager told:

> *"We are apparently doing something right, but we don't know what."*

For the production operations of Heavy Truck Co these gains in market share were very beneficial because they offset the shrinking market trends, and therefore enabled production volumes to remain constant. As a consequence, the processes and structure in the Heavy Truck Co plant have been relatively stable and the management did not have to lay off redundant employees.

Even though the causes for their success are not clear, the management is confident about the future. The human resources manager told:

> *"We are ready for the future because of our high quality products and low costs. The quality of our trucks is acknowledged in the marketplace. Even in a shrinking market there was still room for us to grow. So, when the market starts to grow again the prospects for us are very positive."*

Still, the managers acknowledge that they do not always understand the reasoning of their customers. An example is the paint colour that customers choose for the exterior of their trucks. Every time Heavy Truck Co introduces a new or updated truck model, they select a specific colour to promote the truck. Over the years, the experience of the managers has been that the colour they have used to promote the truck when it was introduced on the market is very popular among customers. However, the colour is only popular for the truck model that was introduced in that colour. So, a colour that was not chosen often for previous truck models may be popular for a new truck model if Heavy Truck Co decides to use that colour to promote the truck. Although this is quite remarkable, it is not clear to Heavy Truck Co's management what the value and meaning of such information is for them.

5.4 Variation Reduction in Organisational Processes

In this section the developments that have taken place at Heavy Truck Co to reduce variation in organisational processes are discussed. The major factor in relation to organisational processes is the risk of poor quality. Relevant processes for Heavy Truck Co are planning processes, production processes and purchasing processes. These issues are dealt with in the remainder of this section.

5.4.1 Planning Processes

Prior to the bankruptcy and the subsequent take-over, Heavy Truck Co did not apply a build-to-order strategy. It built its trucks to plan, which meant that the management would forecast customer demand and built trucks accordingly. Some of these trucks were hard to sell because the management's predictions were not always right. After some time, this meant that Heavy Truck Co' dealerships had nearly 10,000 trucks that were waiting to be sold to a customer.

Since this build-to-plan strategy had contributed to the bankruptcy of Heavy Truck Co, the company started manufacturing according to a build-to-order strategy straight after the take-over by its current owner. So, nowadays trucks are built only after they have been ordered by customers. This prevents a large stock of unsold trucks at the dealerships and at its own plant.

During the same period, Heavy Truck Co also wanted to reduce the stock of supplies at its production facilities. Therefore, Heavy Truck Co demanded suppliers deliver some supplies only when they are necessary (i.e. according to the Just-In-Time principle), and some supplies also according to the production sequence of the trucks. This has resulted in a classification of supplies, based on their stock level and on the way they are delivered to the production line:

- In line sequence delivery. These supplies are delivered per truck in a fixed order, which is the same as the order of the trucks on Heavy Truck Co's assembly line. Delivery of these supplies takes place two to three times per day. This approach leads to zero inventories (see for example Hall, 1983) at Heavy Truck Co. Examples of this kind of supplies are seats, wheels and gearboxes.

- Direct line feeding. These supplies are delivered directly to Heavy Truck Co's production line, based on Heavy Truck Co's needs. This approach leads to a small inventory at Heavy Truck Co's production line but avoids inventory in its warehouses.

- Two-bin system. These supplies are available in two inventory containers, of which one is at the production line and the second one is in the warehouses. When the first container is empty it is replaced by the second one and a new one is ordered from a supplier. This approach leads to inventory in Heavy Truck Co's warehouses and at its production line.

- Products in stock. These are supplies that Heavy Truck Co has in its warehouses. Suppliers deliver them regularly to Heavy Truck Co's warehouses and Heavy Truck Co delivers them internally when needed.

This approach to managing the stock of supplies has reduced the inventory in Heavy Truck Co's warehouses significantly, and as a result the turnover rate of Heavy Truck Co's stock of supplies has increased. The supply chain manager pointed out:

> *"In 1998, we announced proudly that we had reached a turnover rate of our supplies of 27, but in 2003 this number had increased to over 50, which means that, on average, supplies are delivered once per week."*

As this number is an average for all Heavy Truck Co's supplies, some goods are supplied multiple times per day, while others are supplied only once every few weeks. In total, Heavy Truck Co currently uses 8,000 different supplies to assemble its trucks, but, because of the large number of trucks assembled, this results in 26 million parts being supplied per month.

The large number of supplies that Heavy Truck Co currently makes use of is an indicator of the importance of the supply chain. In recent years, Heavy Truck Co has started to focus more on its core competencies of truck assembly, which meant that a larger share of component manufacturing has been outsourced. A development for the future is that Heavy Truck Co will outsource research and product development activities as well. The quality manager explained:

> *"When developing a new truck model, we need to develop all components for that truck simultaneously because the time to market has to be short in order to remain competitive. The simultaneous development of truck components leads to control problems because we are unable to do all this work alone. Therefore, suppliers are increasingly involved to take up parts of the development process."*

Consequently, the supply chain will become even more important than it currently already is.

To cope with the large number of supplies, Heavy Truck Co gradually moves to a modular sourcing approach (see for example Baldwin and Clark, 1997; Schilling, 2000). Currently, the benefits of modular supplies for Heavy Truck Co are limited because the two truck models do not yet have many components in common. For example, the headlights of both truck types are identical, and currently Heavy Truck Co works on a single braking system for all trucks. However, Heavy Truck Co plans to exploit the advantages of modular sourcing more efficiently in the future, because the truck models will then share the same components. It is very difficult to change modules for existing truck designs, so only when new or updated truck types are introduced can Heavy Truck Co take advantage of sharing modules. For example, for future truck models, Heavy Truck Co wants to assemble the cabins of the trucks from the same modules. This would generate major costs savings for Heavy Truck Co and it would reduce the complexity of its assembly processes. These aims are in line with developments in the wider automotive industry, which is looking for ways to use common modules for different models (Oude Weernink, 2006a).

The increase in outsourcing is one of the reasons why the number of employees at Heavy Truck Co has remained relatively stable over the years, despite the growth in truck production that has taken place. Together with improvements in the production processes, outsourcing of production has significantly reduced the number of hours it takes to assemble a truck. Heavy Truck Co's employees spent on average about 200 hours per truck in the year 2000, while they spent about 150 hours per truck in 2003.

Of course Heavy Truck Co also has to deal with short-term demand fluctuations. The management of Heavy Truck Co indicated that it tries to avoid hiring and firing employees regularly. Therefore, it takes short-term demand fluctuations into account when planning the production. The management will estimate how demand will fluctuate in the near future and then cope with that by allowing the delivery time of a new truck to fluctuate as well. So, when demand is temporarily higher than usual, the delivery time of the trucks will become longer. This enables Heavy Truck Co to maintain a stable situation in its organisation.

The downside of the nearly constant number of employees and the low employee turnover is that Heavy Truck Co has not felt the need to develop formal procedures for hiring new employees. The consequences of this are only felt when Heavy Truck Co has to hire new employees because of structurally higher demand and/or to replace employees who left the organisation. The human resources manager explained:

> *"If production needs to increase, the focus is on attracting sufficient new employees and not so much on their quality. No manager wants to be blamed if we do not reach our production targets, so the first priority is to recruit the required number of new employees. Only at a later stage do they start to worry about the quality of the people they hired."*

To some extent, this approach is facilitated by the fact that Heavy Truck Co hires new employees only on a temporary or flex work basis. The new employees are considered for permanent employment only after working on a temporary basis. So, employees who do not comply with the quality demands will not be eligible for a permanent contract. However, during their temporary contract they may have presented an increased risk of defects for Heavy Truck Co.

5.4.2 Production Processes

Over the last ten years, production at Heavy Truck Co has moved from being individual to being group based. The Heavy Truck Co plant is structured in the following way: the different elements of the production process are divided over a number of areas, which are managed by area managers, and each of these areas is divided in a number of production cells, which consist of a number of employees. The composition of these production cells is quite stable. Each employee in a cell can perform multiple tasks, so in case of illness of an employee his or her task can be taken over by colleagues. Employees are also able to perform tasks in the cells adjacent to the one they are working in, so if one cell has a shortage of employees due to for example illness it can hire employees from adjacent cells. The Heavy Truck Co management stimulates production cells to cooperate with each other. The human resources manager pointed out that:

> *"The assessment of the performance of the cells is not only based on effectiveness and efficiency but also on helping other cells by providing employees if necessary. In practice the exchange of employees between the cells is never a problem."*

Within Heavy Truck Co, all performance measurements take place on the level of the production cells. So, each cell is responsible for its own performance, which does not only include performance in terms of production numbers but also in terms of product quality and sickness absence. After measuring the performance of a production cell, Heavy Truck Co provides direct feedback to the production cell. Direct feedback is seen as important within Heavy Truck Co, so the organisation is focused on the development of systems that make direct feedback possible.

To prevent errors in the final product, Heavy Truck Co has increased automation over the last decade. The quality manager explained:

> *"We have eliminated many man dependencies in the production process, which means that all key activities in the production process have been automated to prevent human behaviour from compromising product quality."*

However, the variety of products that Heavy Truck Co produces is very large, and therefore there are still many activities in the production process that are man dependent, because it would require an enormous amount of investments to try to make these activities man independent too.

The use of automated systems and robotics leads to more transparent processes that make it possible to trace back when and how the steps in the production process have taken place. Heavy Truck Co uses some very expensive robots, which check many aspects of the trucks, for example, if enough bolts have been used for attaching one part to the other, and if the bolts have been fastened tight enough. If the robot senses any deviance from pre-set standards, it will not let the truck continue further down the production line before the problem is corrected. So, these robots are used to check the work of the employees and not so much to replace the employees. The quality manager believes that in the whole automotive and truck industry the use of robots for assembly activities is declining, because the performance of robots has quite often been disappointing. Even when robots are only used to check the work of employees, the success has been mixed. The quality manager pointed out:

> *"The use of robots results in varying levels of commitment amongst employees who operate them. Some do not pay much attention to the production line because they believe the robot will do the job. Yet, others are measuring all kinds of things on the trucks, even though this is in principle not necessary because all measurements are done automatically. However, if defects and problems arise, the second group feels much more responsible and involved."*

So, acceptance of robotics by the employees is important for the success of the robots, and thereby for the success of the whole organisation. Robots can contribute to the quality of the trucks but the managers of Heavy Truck Co were agreed that the benefits of technology are limited.

However, relying only on human judgement is also not sufficient, an example of which are the snap checks of finished trucks. Heavy Truck Co's owner puts much emphasis on the delivery quality of a truck, which is the number of deficiencies in a new truck at the moment of its delivery to the customer. Heavy Truck Co's owner checks this by entering Heavy Truck Co's plant during the night and taking a couple of finished trucks for examination. From a quality perspective these audits are not satisfactory because the measures that are used are in many cases insufficient. They test, for example, if the bolts on the truck are properly tightened.

This is being done by hand, although a hand-tight bolt not at all guarantees that the bolt has been tightened with the required force. So, for these purposes, robots would be very useful.

Nevertheless, the delivery quality audits do result in issues for improvement. The quality manager pointed out that:

> *"Structural incidents regarding delivery quality of the trucks are recorded in a systematic way. By doing so, we are able to find out what the most common flaws in delivery quality are. Before we started to work like this, nobody felt really responsible for the problems because responsibility for them nearly always falls in between two departments."*

Therefore, the systematic recording and solving of the problems is a major step forward for Heavy Truck Co. The top ten of most common flaws is addressed by Heavy Truck Co by means of concrete improvement projects.

The delivery quality is not only checked for the complete truck, but also for major components like the engine. The performance and reliability of the engine is obviously a major criterion for truck buyers. Heavy Truck Co builds its trucks to last at least 1.6 million kilometres, so the engine should be capable of running all that time without major problems, which includes the durability to comply with environmental legislation. Therefore, Heavy Truck Co constantly checks the quality of its engines. It does so by completely disassembling one engine every day. The production manager commented:

> *"Every part of the engine is tested to see if it is working the way it should work. If problems are detected that are directly related to the employee who did the assembly, immediate and direct feedback is given to that employee. The employee is explained what has gone wrong and how it could have been prevented."*

If it is a problem that shows up frequently and that can be made man independent, the process is adjusted to prevent the problem from happening again. One way in which this can be done is by means of warning signals that light up if an engine is coming down the production line that should get a different treatment with respect to some engine parts because it has to comply with specific customer demands.

Heavy Truck Co also works on poka yoke or mistake-proofing (see Shingo, 1987) to make it nearly impossible to make mistakes. A possible application of poka yoke in the near future will be a camera system that films each step in the assembly process of an engine and stops the production line if a part of the engine has not been assembled correctly.

During the daily quality measurements on the engines, each error is rated on a scale from not severe to very severe. Not severe errors are mostly esthetical (e.g. the spray painting of the engine has not been done properly), while the very severe errors are likely to lead to engine failure. Heavy Truck Co provides not only immediate and direct feedback to the employee who is responsible for the error, but also to other employees down the production line who could have noticed the error but did not report it. The production manager explained:

> *"By explaining that failure to report an error may lead to high costs and losses, we try to make employees feel responsible for their own errors and those of their colleagues. It is important that employees feel that their production cell operates as a team. If a production cell operates as a team, it is possible for employees to communicate to their team members in a positive way if an error has been made."*

Apart from the daily quality tests in which an engine is completely disassembled, the shop floor employees also conduct small tests by themselves. These tests are mostly checks to guarantee that, for example, parts have been installed in the engine and that bolts have been tightened. All specifications of each engine are described in an engine book. Each engine has its engine book, which stays with the engine during the entire assembly process. The employees can look in the engine book to see what parts have to be installed in or on the engine and they can see what checks have to be conducted by each employee on that engine. In the past this list of checks consisted of 180 items. The problem with such long list of items is that an experienced employee will mark all his or her tests as completed before he or she even starts working on the engine. To reduce this risk, the number of items has been reduced, but currently the engine book is still not operating the way it should because there are other practical problems with the engine book. Firstly, it is difficult to make last minute adjustments to the engine because that would mean that part of the engine book has to be rewritten. Secondly, when the engine enters the paint shop for spray painting of the exterior of the engine, the engine book has to be taken away from it until the spray painting is finished, which may lead to mistakes (e.g. attaching an engine book to the wrong engine).

To accommodate for these practical problems with the engine book, Heavy Truck Co is currently working on a digital version of the engine book. This digital engine book should facilitate tracking and tracing of exactly when the engine has been at what stage of the production process, and what operations have been completed on it. The production manager pointed out that:

> *"This allows for quick interventions if an error is detected by the system. Moreover, it allows for dynamic adjustment of the engine specifications if a customer wants to make last minute changes to the engine. By attaching an electronic mark to each engine, the problem of mixing up engine books when the engines are in the paint shop is also prevented."*

The instructions in the digital engine book can be presented visually to the employees by means of computer screens. This makes it possible to warn an employee that he or she has to do a specific task on an engine, or to warn him or her that the engine they are working on should not have certain parts installed on it.

5.4.3 Purchasing Processes

The way in which Heavy Truck Co manages the quality of its supplies has changed drastically over the last decades. During the period before 1980, Heavy Truck Co used traditional inspection methods (see for example Dale, 2003) to assess the quality of incoming supplies. This was done by means of samples taken from the incoming supplies. During those years, Heavy Truck Co employed between 40 and 45 people who had a full-time job inspecting samples of the procured products.

In the 1980s, Heavy Truck Co's management requested a researcher to undertake a study on supply management practices in the automotive industry. The main conclusions from this study were that inspection of incoming products was not sufficient anymore and that the automotive industry had therefore shifted from relying on inspections to demanding quality assurance from its suppliers. The automotive industry was applying Ford's Q101 approach (see for example Hoyle, 2000), which forces suppliers to develop a quality assurance system according to the criteria defined by Ford. By doing so, the manufacturers made their suppliers responsible for the quality of the supplies. Based on the results of the study, Heavy Truck Co started with a supplier quality assurance program. The supply chain manager pointed out that:

> *"Our supplier quality assurance program was a formal approach to develop a systematic procedure in relation to the control of incoming products. The implementation of this program meant a change from past policy, because in the past the main criterion for the selection of suppliers had been price. In 1980, a start was made to select suppliers both on price and on contractual quality agreements."*

To achieve this, Heavy Truck Co started with audits at the supplier's site. Based on a supplier's audit and on the products that the supplier was selling to Heavy Truck Co, a quality agreement was developed in which process flows and checks in the processes at the supplier's site were defined and documented. As a consequence of this quality agreement, it was no longer necessary for Heavy Truck Co to check the incoming products of that supplier by means of inspection. Therefore, the products of the suppliers that had a quality agreement with Heavy Truck Co were no longer subjected to inspection. However, to guarantee good quality supplies, Heavy Truck Co had to conduct audits at these suppliers' sites on a regular basis.

This approach has been heavily developed and extended from the early 1990s. Over the years, an increasing number of suppliers have signed a quality agreement with Heavy Truck Co. Heavy Truck Co supported this internally by allowing employees to buy supplies only from suppliers that had a quality agreement. Consequently, price was no longer the major criterion on which suppliers were selected. By the time of the interviews, 75% of all bought in supplies were not tested anymore by means of inspections. The supply chain manager commented that:

> *"Even if we still wanted to inspect all incoming supplies, this would be virtually impossible, because it would mean that about 75 to 80 persons would be needed to do the actual inspections."*

In addition, the costs would be much higher than in the past because of the need for large investments in sophisticated testing machines, which would be necessary to test the many high-tech supplies that are used these days in truck production.

Because Heavy Truck Co has its own quality agreements with suppliers, the management does not feel a need to demand external certification of the suppliers' quality systems. Therefore, Heavy Truck Co does not demand that suppliers have, for example, an ISO 9000 series certificate (see ISO, 2000; ISO, 2005; Van der Wiele et al., 2005), although it helps suppliers to comply with Heavy Truck Co's criteria if they are certified. Another reason why Heavy Truck Co does not demand external certification from its suppliers is the fact that many of its suppliers are very small companies that produce low volume supplies for Heavy Truck Co. For these suppliers it is too costly to set up a quality management system which will get external certification. However, about 65% of Heavy Truck Co's suppliers have an ISO 9000 certificate because these suppliers also supply large automotive manufacturers that demand ISO 9000 certification. The top-100 suppliers of Heavy Truck Co, which account for 85% of supplies, are all certified.

From the end of the 1990s, Heavy Truck Co has taken supplier quality a step further. Heavy Truck Co realised that its core competence was to bring together different components into a final product (i.e. a truck), regardless of where these components come from. The supply chain manager explained that:

> *"There was a shift towards interface management as a core competence. We had the intention to increase production significantly, and the jump in truck production from 12,000 a year in the mid 1990s to 41,000 a year in 2003 was only possible because a lot of activities could be outsourced and we could become the end assembler."*

This meant a shift in thinking from efficiency in Heavy Truck Co's internal processes, towards developing relationships with suppliers. So, the role of the suppliers has had to change. Heavy Truck Co has started to make much more use of the knowledge that is available at the suppliers because that knowledge can be used to innovate and to develop more efficient products. Therefore, Heavy Truck Co has involved its suppliers already since the late 1990s in new product development. Heavy Truck Co's management has become aware of the benefits of supplier knowledge relatively early, since major manufacturers in the wider automotive industry are only now realising the potential of the knowledge that is available at their suppliers (see for example Connelly and Sherefkin, 2005; Kisiel, 2005; Rechtin, 2006a; Stein, 2006).

In order to be able to increase the production of trucks without having to expand its production facilities, Heavy Truck Co started to outsource the production of complete modules to its suppliers. As these modules combine several components, module suppliers need to be more capable than suppliers of individual components. In addition, module suppliers need to be able to manage second and higher tier suppliers. Not all existing suppliers were able to make the change from individual supplies to modular sourcing. The supply chain manager pointed out that:

> *"The mentioned changes in our purchasing strategy have led to a policy and practice of fewer suppliers. The number of suppliers went down from 900 in the mid 1990s to 439 in 2004. We aim to reduce this number further to around 400 but much less than that will probably be impossible."*

Heavy Truck Co currently uses between 175 and 200 different product families, which are groups of similar supplies that require a certain expertise to manufacture. Only very few suppliers manufacture more than one product family. So, if Heavy Truck Co wants to have at least two suppliers per product family, the minimum total number of suppliers will be around 400. However, by combining different components in one module, the number of suppliers could go down a little more in the future.

In the relationship between Heavy Truck Co and its suppliers, the importance of information technology has increased considerably over the years. It is essential for Heavy Truck Co and its suppliers that relevant and accurate information is available in real-time. The assembly time of a truck has been reduced from 200 to 150 hours in just three years, and this development still continues. Therefore, all parties involved have little time to react in case of problems. To cope with these demands, Heavy Truck Co uses a supplier management system, which records all data and information about suppliers to monitor their individual performance. The suppliers can also access their performance via the on-line interface of the supplier management system.

5.5 Continuous Improvement

In this section Heavy Truck Co's efforts to achieve and maintain a culture of continuous improvement are discussed. Developments that have had an influence on continuous improvement are explained. The major factor underlying these developments has been the need to more closely involve different parties (e.g. management, employees and suppliers) in the process of continuous improvement. Relevant issues for Heavy Truck Co are process improvement, improvement of employee knowledge and skills, and supplier improvement. These issues are dealt with in the remainder of this section.

5.5.1 Process Improvement

One of the first things that Heavy Truck Co was ordered to do after the take-over by its current owner was lowering its costs and thereby improving its financial position. The first reaction of Heavy Truck Co to this demand was looking for all kinds of quick and easy improvement projects. The quality manager explained:

> *"To bring down inventory turnover time, we started to throw away all supplies that were not directly needed for production. We also increased the price of coffee for our employees from 9 to 11 cents per cup. However, these measures were not smart and did not bring the savings that were needed because they were just an initial reaction."*

In subsequent rounds of measures, Heavy Truck Co had made plans upfront about how to bring down the costs in a sensible way, which was a much more successful approach.

Heavy Truck Co's improvement projects started to gain momentum when it began applying the Six Sigma improvement methodology (see for example Bhote and Bhote, 1991; Pande et al., 2000; Pyzdek, 2003). Since 1998, Heavy Truck Co has used Six Sigma as a quality improvement tool because Heavy Truck Co's owner demanded its subsidiaries to use Six Sigma. All Six Sigma projects at Heavy Truck Co have been aimed at financial gains, which means that a certain level of savings should be realised by improving a process.

During the last couple of years, the Six Sigma approach has proved to be a successful way of working on improvements for Heavy Truck Co. The quality manager explained that:

> *"Six Sigma is a structured problem-solving tool, which consists of three elements. Firstly, decision making based on facts. Secondly, a framework approach that implies a structured way of working towards a solution. Thirdly, translation of results in financial gains."*

Over the last couple of years, Six Sigma projects have resulted in savings of nearly 20 million Euros per year for Heavy Truck Co, which the management considers to be a major success. These savings easily surpassed the demands of Heavy Truck Co's owner, which has demanded savings of 15 million Euros per year.

The total amount of projected savings is simply divided over the different departments within Heavy Truck Co, although most Six Sigma projects can be found within the production department. Each department should come up with concrete savings projects that will save costs to the extent necessary to fulfil the demands of Heavy Truck Co's owner. The departments are free to choose their projects. The quality department monitors the way in which the departments conduct the Six Sigma projects (i.e. if the Six Sigma method is used properly), and it checks whether the employees have received the required training. The financial controllers check the financial benefits of the Six Sigma projects. Projects only count as successful Six Sigma projects if the controllers indicate that they have resulted in financial benefits.

For the Six Sigma program, Heavy Truck Co trained 600 employees according to the 'belt' system (see for example Pyzdek, 2003). The training of the employees is the responsibility of the different departments within Heavy Truck Co. Top management values the belt training, which it emphasises by taking it into account when assessing an employee's eligibility for promotion within the company.

The Six Sigma projects usually address the areas that cause most of the problems for a department and/or its customers. The quality manager commented that:

> *"Many projects are related to throughput rates, productivity, and logistical issues. Sometimes projects are based on explicit customer complaints, but mostly they are based on internal deficiencies."*

Despite the successes that have been achieved with Six Sigma, some Heavy Truck Co managers expect that the project-based approach to Six Sigma will not remain successful in the future when many costs have been reduced substantially already. They believe that the Six Sigma projects will become less successful when the waste has been eliminated. An example was given of a department at Heavy Truck Co that employs 20% of the number of employees at a comparable department at one of Heavy Truck Co's competitors, notwithstanding the fact that Heavy Truck Co is twice as large as this competitor. Therefore, it seems impossible to reduce the headcount of this department further. Similar developments are also going on in other parts of the Heavy Truck Co organisation. The human resources manager pointed out that:

> *"Once the waste has been eliminated, the Six Sigma approach reaches a stage of maturity that calls for a different way of working. Until now, we have applied Six Sigma in projects that were designed to remove the peaks of variation from processes through process control methods."*

Once the processes are under control, there is a need for an approach that prevents new losses from emerging. The human resources manager went on to argue that:

> *"Instead of using Six Sigma in specific improvement projects, the Six Sigma mindset should be built-in into the organisation to eliminate variation and costs in a prevention mode type of thinking."*

The fact that the amount of money that has to be saved by means of these projects is imposed upon the departments leads some people to redefine already realised improvements as Six Sigma projects. The production manager pointed out that:

> *"In some cases, inefficiencies that have already been eradicated by other means are still written up according to the Six Sigma demands to classify it as a genuine Six Sigma improvement project."*

This behaviour undermines the intentions of the Six Sigma approach because in these cases the savings are recorded as Six Sigma savings while they were already realised by other means. Another problem with imposing targets for Six Sigma improvements is the selection of straightforward improvement projects as Six Sigma projects. The human resources manager explained:

> *"In an effort to come up with sufficient Six Sigma projects, some managers try to define straightforward improvements in processes as a genuine Six Sigma project."*

An example of this is a project around inconvenience surcharges, which are surcharges that employees receive because of working under noisy and dangerous circumstances. For years, nobody had paid attention to the level of the surcharges, and once someone started to study the issue, he realised that Heavy Truck Co could save about 300,000 Euros on the surcharges because improved working conditions had reduced the amount of money that Heavy Truck Co was obliged to pay. Some people in the organisation then suggested defining these savings as a Six Sigma project, although it was just a matter of terminating some of the surcharge payments. This example indicates that there clearly is a need for a more mature role for Six Sigma in the organisation. Until now, the focus may have been too much on the costs side. The production manager pointed out that:

> *"In the current approach, Six Sigma is used for costs savings in existing processes. However, the Six Sigma focus should also encompass the design phase of products because this will lead to prevention of problems before they happen. These soft savings do not result in direct financial savings but they will in the long run save a lot of money."*

Six Sigma is not the only way in which Heavy Truck Co improves its processes. Another tool that is used by Heavy Truck Co to improve processes is Kaizen (i.e. gradual and orderly continuous improvement, see Imai, 1997). Kaizen is used in two ways. Firstly, for individuals to continuously improve their own working practices. Secondly, it is implemented by means of 'blitzes', which are very short improvement projects (Laraia et al., 1999). A Kaizen blitz means that an issue is picked up and improved/implemented within four days. These Kaizen blitzes are used to track down waste and eliminate it. A Kaizen blitz is defined as a project and is conducted in a structured way (like the Six Sigma projects).

During one of the Kaizen improvement projects, it became visible that some employees walk no less than 15 kilometres per day. By improving the processes, the walking distance for these employees can be reduced drastically. This means that the same employee can spend a larger share of his working time in a productive way, which is a benefit that Heavy Truck Co needs to reach its growth targets. The quality manager commented that:

> *"We want to grow in market share, however, production capacity cannot grow enough to accommodate for the growth in production. This means that we need to increase productivity, to produce more with the same amount of capital goods. Therefore, the Kaizen improvement projects are very important to us."*

The achieved successes that have resulted from the Kaizen program in combination with Six Sigma, have generated top management interest from Heavy Truck Co's owner. Especially the cost savings are attractive to top management, since Heavy Truck Co has generated total savings of over 60 million Euros after three years of using Kaizen and Six Sigma.

Apart from process improvements realised by means of specific improvement programs, Heavy Truck Co also implements improvements when existing equipment has worn out and when changes in government regulations demand it. An example of such an improvement is the replacement of the assembly line in the engine assembly department. The production manager explained that:

> *"Until 1994, we used a manually operated production line for engine assembly. Each engine was manually moved for 960 metres through the plant and during that process it had*

> *to be lifted and lowered 25 times to make it possible to work both underneath the engine and on the top of it."*

At that time, government regulations, rules for ergonomic working conditions, quality demands, and worn out machinery forced Heavy Truck Co to renew large parts of the production line in the engine assembly department. Automated carts that move the engines have replaced the manual movement of engines by means of manpower. These automated carts are programmed so that they know when to lift the engine to make working underneath it possible and when to lower the engine for work on top of it. Although these carts are now automated, it is still possible for the employees to adjust them. If an employee has some difficulties with installing a certain part on the engine, he or she can keep the cart at its place until he or she is ready. The next carts in line will then automatically wait until the previous one has moved on. The same goes for the automatic height adjustment of the engines on the carts. The carts will do this automatically but the employee has the possibility to lower or lift the engine if necessary.

The testing facilities of the engine assembly department have also been improved significantly. In 1998, Heavy Truck Co needed three shifts of employees and eight test rooms to test the total output of eighty engines per day. In 2004, Heavy Truck Co needed two shifts and six test rooms to test the total output, which had increased to 145 engines per day. The testing itself has been completely automated. In 1998, it was still man dependent but in 2004 it is completely man independent. The new automated test equipment makes it not only possible to shorten the test time of an engine, but it also levels out any differences in engine power. So, with the new test equipment all engines of the same type have exactly the same amount of horsepower, which means that the process improvements have resulted in concrete product improvements as well.

When Heavy Truck Co renewed the production line in the engine assembly plant, it also introduced four robots (for manufacturing engine parts like cylinder heads and connection rods). Automating the adjustment of valve rocker clearance was very important to meet quality demands, so in the new production line more process steps are automated than in the previous one. The production manager explained that:

> *"This decreases the man dependence of the whole production line, which has advantages but it also has its limitations. It is not possible to make the complete process man independent*

because the processes will to some extent always be dependent on the employees."

Another important category of process improvements are the ones that result from quality issues. The engine assembly plant has a formal consultation structure with respect to quality issues. At the lowest level there is a quality improvement team, which meets every week to discuss quality issues. These are mostly the issues that show up internally (after testing) or that are communicated to Heavy Truck Co by the customers. At a higher level there is the quality team, which meets every four weeks. The issues that are discussed by the quality team are more conceptual than the ones that are discussed by the quality improvement team. The quality team comes up with, for example, improvements that should be implemented when a new engine type will be developed (i.e. design issues). All quality related issues are classified by the way they can be solved:

1. By means of adjustments at a conceptual level (i.e. design changes)

2. By means of adjusting the process

3. By instructing the employee who is responsible for the quality issue

Quality issues of the first category are addressed by the quality team, while the quality improvement team deals with quality issues of the second and third category. If neither the quality improvement team nor the quality team can solve a quality issue, the issue is brought under the attention of the responsible department manager. If he or she is also unable to solve the quality issue, it is presented to the quality manager of Heavy Truck Co.

The combination of the different process improvement approaches seems to work well for Heavy Truck Co. However, even formal improvement systems and approaches do not guarantee success, because they still require people in the organisation who come up with creative ideas at the right moment. Creative ideas about process improvements can lead to advantages over competitors. An example is a recent benchmarking study, which made clear that some car manufacturers are not only outsourcing the supply of certain products but also the assembly of those products in the vehicles (i.e. the suppliers work partly at the site of the car manufacturers). Soon thereafter, Heavy Truck Co found out that one of its competitors does not only outsource the production of paint but also the process of spraying the paint on the trucks, which may result in cost benefits for this competitor.

However, creativity alone is not enough, according to the management of Heavy Truck Co. The quality manager explained that:

> *"The right timing is crucial to get top management support in the first place. It is no use to start improvement initiatives in existing processes that require a lot of investments because top management is most likely not willing to invest too much money in these existing processes."*

The moment when investments in new processes are considered, offers an opportunity to get top management support for improvement initiatives, because at such occasions these initiatives usually do not require much additional investment.

An additional problem for Heavy Truck Co is that quality and improvement initiatives are not something that is clear-cut for everyone in the organisation. Every manager in the organisation is different, and therefore top management needs to instruct all these different managers about the quality initiative that it wants to implement. Although the quality initiative is the same throughout the organisation, it needs to be communicated differently to the different managers in the organisation, which requires a lot of efforts. The quality manager made the following comparison:

> *"Quality management systems are like a pack of flour: you can bake many different cakes from the same pack of flour."*

5.5.2 Improvement of Employee Knowledge and Skills

Heavy Truck Co's efforts to improve the knowledge and skills of its employees go back a long time. In the 1980s, the quality department at Heavy Truck Co was mostly composed of psychologists. They focused on the softer aspects of quality and human behaviour. These quality efforts were not very successful, because there was not much discipline within the organisation and there was also no commitment from top management. The quality manager pointed out that:

> *"Quality was seen as something that had to be done by someone in the organisation, but the management team should surely not do it."*

Different initiatives were developed, but they disappeared just as soon as they came. Heavy Truck Co applied aspects of the quality thinking of Feigenbaum (1986), and later it started working with the ideas of Crosby (1979). The quality manager commented that:

> *"Quality at that time meant a lot of meetings and very few concrete improvement projects that contributed to a healthy business."*

Soon thereafter, Heavy Truck Co's management started to realise that the knowledge and expertise of the shop floor employees could be used to the benefit of the whole organisation. Therefore, top management wanted a system with which employees could be consulted to learn from their experiences on the work floor. The idea of Quality Circles (see Ishikawa, 1982; 1984; 1990) was embraced by Heavy Truck Co as an approach to involve the shop floor employees in the organisational processes. During the 1980s, the Quality Circles had been used throughout the organisation. At that time, Heavy Truck Co was ready for the Quality Circles approach because it already had forms of work consultation and meetings, which are important prerequisites for the success of Quality Circles. Heavy Truck Co was successful with its Quality Circles approach, which resulted in many prizes and awards from quality associations.

However, there were also risks to the Quality Circles, because some departments in the organisation were still applying a scientific management approach (see Taylor, 1911; Hunt, 1924). Consequently, employees in these departments are forced into a pattern of doing what the management instructs them to do without thinking about it themselves. Yet, the Quality Circles allow these employees to think for themselves for about one hour per week. The human resources manager pointed out that:

> *"Employees enjoy themselves very much during that one hour because they are able to improve things. But, the rest of the week they still have to do what they are told to do. Employees start to ask why they are not allowed to think for themselves during the whole week. Therefore, they lose their enthusiasm for the improvement projects by means of the Quality Circles."*

Today, Heavy Truck Co still believes that shop floor employees should have an important role in problem solving and continuous improvement activities. Over the last couple of years, Heavy Truck Co has developed the perfect workstation concept, which is based on the Kaizen philosophy and implies that shop floor employees have a large influence on how to solve problems. Incidental quality problems are addressed by means of the perfect workstation concept, because this kind of problems is most often the result of human behaviour. The quality manager pointed out that:

> *"In the past, solutions to this kind of problems were mostly given to the shop floor employees in a top-down fashion. Over time, we started to realise that the technical knowledge is in the brains of the shop floor workers, instead of in the brains of the management."*

Therefore, management now has a more facilitating role. Heavy Truck Co started experimenting with the perfect workstation concept in 2003 and these experiments proved to be successful. There was an 80% increase in the number of incidental problems that could be solved as a result of these experiments.

The influence that individual employees can have on problem solving and organisational improvements can be limited by the teams in which they operate. For example, ten years ago, a problem with the teams (Heavy Truck Co calls them production cells) was that the important and responsible tasks within the cell were done by a very small number of employees. This situation was stimulated by many managers, who found it convenient that they only had to communicate with a small number of employees because these employees would take care of the issues in their cells. However, the quality manager pointed out that:

> *"The increased complexity of the production process can only be addressed if all employees are able to carry out different tasks. Trying to make all processes man independent proved to be impossible because of the increased complexity."*

Therefore, the quality department started to work on a world-class manufacturing program, which aimed to make production cells more flexible by distributing the different tasks within the cells more evenly.

In order for individual employees to be able to contribute to process improvements, they need to have the necessary skills and experience. Heavy Truck Co's training program for employees consists of formal, as well as informal training. The formal part encompasses:

- A two and a half day introduction program for new employees.
- A task manual, which is part of a decentralised introduction for new employees at the level of their department.
- Standard training (e.g. for obtaining or renewing welding certificates and other certificates that have to be renewed on a regular basis).
- Training for the development of employees. This contains both job related training to improve skills, as well as non-job related training, like first aid training.

Although Heavy Truck Co offers these forms of formal training to its employees, most of the training within the organisation is informal training. Employees learn different skills by observing what their colleagues are doing, and they practise these skills when they have to replace their colleague in case of illness or holidays.

Each employee has a task book in which a record is kept of that person's expertise, skills (by means of a skill matrix), and instructions for his or her work activities. The employees in a production cell are responsible for maintaining the skill matrices. Based on an employee's skill matrix the management decides if that employee is allowed to perform a given task. The training needs for each employee are based on his or her skill matrix as well. The production manager pointed out that:

> *"Only the more skilled employees are allowed to participate in external training programs. This option is, however, not explicitly communicated to the employees because we fear losing our most talented employees, if they feel that they can get a better position elsewhere because of the training programs they took part in."*

At the corporate level, Heavy Truck Co's owner, over the last few years, has started to offer leadership training for managers at all levels in the organisation. This training is not meant to teach managers the desired leadership style, but instead it is meant to provide feedback and reflection on a manager's leadership style. Apart from this leadership training, Heavy Truck Co's managers also receive Six Sigma training, in order to be able to manage improvement projects. For example, the human resources manager has been trained in Six Sigma and has become a black belt in 2002. Since then, he has been involved in a number of Six Sigma projects, which were focused on reducing illness leave, improving the safety of work, and improving the mechanism for selecting potential employees.

Heavy Truck Co's budgets for training and development of employees have increased substantially over the last few years. In 2003, Heavy Truck Co had a training budget of 1.5 million Euros and for 2004 this budget would again increase considerably. Given the decreasing training budgets in many competing companies, this clearly shows Heavy Truck Co's commitment to training and development. The human resources manager explained that:

> *"The world will only get more complex in the future. As a result of that, knowledge will deteriorate much faster than it has ever done before. To survive in this complex world, everybody in the organisation needs to keep learning to increase knowledge and improve skills."*

He continued to argue that:

> *"The increasing complexity will make sure that people will again become much more important in the production process, because people are most capable to cope with complex situations. The more complex things get, the harder they can be solved by systems and machines."*

Despite Heavy Truck Co's efforts to train managers and shop floor employees, the interviewed managers were agreed that the mentality of the employees is of key importance for the success of the organisation. The human resources manager pointed out that:

> *"People who strive for a successful career are very important for an organisation because they are willing to go that extra mile for their employer."*

The interviewed managers believe that employees who are not career oriented may find it difficult to cope with the increased complexity of today's assembly processes. During the last decade, Heavy Truck Co has expanded the responsibilities of individual employees by training them for a wider range of tasks. However, the increasing complexity of the assembly processes makes each task more demanding. This may mean that shop floor employees should again become specialists of just a small part of the whole assembly process (i.e. in a Taylorian way, see Taylor, 1911; Hunt, 1924). So, even if an employee only has to focus on a small part of the assembly process, he or she still has to be able to work an all different types of product variants. For employees who are not career oriented this may be all they can handle. However, this development would not be without risks because it could stimulate employees not to think about their job anymore, which can make them become stuck in inefficient working practices. The production manager pointed out that:

> *"The trick is to use the brains of the employees in an effective way, while at the same time splitting up the production process in an efficient way. By doing so, the employees can become experts in their part of the production process without being turned into human machines."*

The disadvantage of making employees experts on part of the assembly process is that they will not have a good overview of the whole process anymore. This may make it difficult for them to generate ideas about improvements that would benefit the assembly process as a whole. The production manager explained:

> *"Only very few employees are really willing to take responsibilities."*

5.5.3 Supplier Improvement

Heavy Truck Co's supplier base has undergone major changes during the last decade. The introduction of modular sourcing during this period has proven to be a difficult switch for many suppliers. In 1995, Heavy Truck Co asked an automotive research institute to undertake a country-wide study on the supplier structure in the automotive industry. This study concluded that many automotive suppliers did not see the trend towards modularisation of the supplies, and of the 1,400 suppliers investigated, only around ten were found to be able to become module suppliers. This was an alarming number for Heavy Truck Co's management. One of the reasons why this number was so high was the fact that in the country where Heavy Truck Co is located many of the existing suppliers were small suppliers, which were not able or willing to move their businesses towards higher knowledge levels. Consequently, in subsequent years these suppliers lost Heavy Truck Co contracts to foreign suppliers, and they became second tier suppliers (i.e. suppliers to the module suppliers) of Heavy Truck Co. The supply chain manager pointed out that:

> *"Suppliers that wanted to keep their business with us had to increase their levels of product development, and they also had to find ways to deliver the modules at the right time, at the right place, in the right order etcetera."*

Few of Heavy Truck Co's existing suppliers were able to adapt and become module suppliers. Foreign suppliers turned out to be more sophisticated than domestic ones, because they acknowledged the modularisation trend in time. Therefore, many domestic suppliers were replaced by foreign ones. However, not all Heavy Truck Co's supplies could be transformed into modules. The interviewed managers explained that there is a difference between modules and systems. A module is for example a light unit that is built by a supplier as a complete unit and can be installed into the truck with relatively little effort. A system is for example a breaking system with all the elements that are related to it. The different components of the braking system cannot be integrated into a single module because they have to be installed at various places in the truck. Heavy Truck Co purchases these components as a complete system from a single supplier. Apart from these modules and systems, today there still is a considerable amount of the traditional single-part supplies left at Heavy Truck Co. To an extent this is caused by the number of trucks that Heavy Truck Co sells, because module suppliers need high production volumes to win back costs of investments and development costs.

With the increase in outsourcing of product modules, Heavy Truck Co also has had to modify the way it addresses quality problems at its suppliers. Currently, Heavy Truck Co uses two strategies to cope with supplier quality issues:

1. Supplier readiness reviews. By means of these reviews, Heavy Truck Co assesses if a supplier is capable of delivering the agreed supplies, both in terms of volumes as well as quality. A very important aspect of these reviews is the extent to which a supplier has control over its own supply chain. These reviews are done by one Six Sigma black belt employee and twelve quality assurance employees, who work for Heavy Truck Co's supplier department.

2. Focus on the design process. Heavy Truck Co started to realise that most warranty issues were related to bad design, instead of production errors. This knowledge shifted Heavy Truck Co's supplier focus from operational quality agreements to the quality of the design process. Heavy Truck Co's managers are convinced that the number of quality problems during the lifetime of a truck can be reduced significantly if quality and reliability are already taken into account during the design of systems and modules. Advanced Product Quality Planning (APQP), which is part of the QS 9000 and ISO/TS 16949 quality system standards (ISO, 2002), is a structured approach for designing quality into new systems and modules (see for example Stamatis, 1998).

However, the design of modules and systems is to a large extent determined by the design of the truck itself. Therefore, it may not always be possible for suppliers to design components in such a way that quality problems can be prevented during the lifetime of a truck. Therefore, Heavy Truck Co has started in the last couple of years to involve its suppliers in the development process of new truck models and modifications in current truck models. In a joint effort between Heavy Truck Co and its suppliers, Heavy Truck Co's reliability demands are then translated into the design of modules and systems. The supply chain manager commented that:

> *"Robust design is becoming a key issue in the discussions with the suppliers. Focusing on the design phase of the trucks not only increases the quality but also the efficiency of the production processes throughout the supply chain."*

The real benefits of this approach are still some time away because of the large time lags in truck production. Many changes and improvements can only be applied to new or updated truck models. In most cases it is too costly to change fundamental things on a current model. So, gradually the results of this approach will become visible, although the number of product recalls of Heavy Truck Co has already decreased over the last couple of years.

The suppliers that take part in the discussions around the design of new or updated modules and systems agree with development plans, which describe critical elements and aspects of products, including necessary quality tests. The suppliers are asked in advance if they are able to deliver the module or system according to the requirements of the development plan and if they are able to deliver the module or system in the volumes that Heavy Truck Co needs. If suppliers are able to do so, Heavy Truck Co grants them long-term (i.e. five year) contracts, which means that the relationship between Heavy Truck Co and these suppliers changes from a market exchange to a relational exchange (Frazier et al., 1988). Part of the contracts is the demand that the suppliers continuously improve their processes and that these improvements result in concrete savings. These savings are to the benefit of Heavy Truck Co only, since the suppliers do not get a part of the savings. Heavy Truck Co's managers feel that such a bonus to the supplier would increase Heavy Truck Co's costs compared to its competitors. The supply chain manager explained:

> *"Our competitors also reduce costs, so if we allow suppliers to keep part of the savings that are achieved by them, our*

> *costs level would get too high over time. We cannot afford this because the prices of trucks are constantly under pressure from the transport market sector."*

The margins in the transport sector are low and therefore companies in the transport sector put pressure on Heavy Truck Co to keep the prices of trucks as low as possible.

Heavy Truck Co's suppliers are successful in reducing the costs of the components they sell to Heavy Truck Co. During the last couple of years, they have realised yearly savings to the amount of ten million Euros. However, Heavy Truck Co does not have a position that allows it to dictate the market, because its production volumes are simply too low. The supply chain manager pointed out that:

> *"Many of our suppliers also supply the much larger passenger car manufacturers. Therefore, we cannot demand big reductions in the price of our supplies. If we tried to do so, the big suppliers would just refuse to sell us their products."*

With respect to the small suppliers, Heavy Truck Co has a much more dominant position but using that dominance could result in the bankruptcy of many of these small suppliers. Consequently, Heavy Truck Co has not much market power in the supplier market, but in the case of the large suppliers Heavy Truck Co can benefit from improvements in these suppliers' efficiency that have been demanded by the passenger car industry.

Over the last few years, Heavy Truck Co has started helping the smaller suppliers with improving their processes and removing waste. In such cases, Heavy Truck Co and suppliers cooperate in Six Sigma projects as a structured approach to work on improvements. A recent example is a Six Sigma improvement project for the fuel pumps of trucks. Together with its supplier, Heavy Truck Co was able to improve these fuel pumps significantly. Heavy Truck Co also helps its suppliers with setting up Six Sigma projects in their own organisations. In addition, workshops and training are provided by Heavy Truck Co to suppliers that are interested in applying Six Sigma. However, the training capacity of Heavy Truck Co is limited because Heavy Truck Co does not have the facilities and manpower for training large groups of people.

The interviewed managers expect a continuation of the trend of involving suppliers in the design process of new or modified truck types. This involvement is taken a step further by means of Heavy Truck Co's recently developed design for Six Sigma program (see for example Creveling et al., 2002; Pande et al., 2004). This program implies that Heavy Truck Co discusses the process capabilities of processes that suppliers are offering for future supplies. These discussions take place 1.5 to 2 years before the first production will start. The supply chain manager explained that:

> *"Discussing the process capabilities of suppliers' processes before the first product has been produced, avoids difficulties during the actual production process of a new truck."*

Therefore, Heavy Truck Co will use its design for Six Sigma program for all new product development projects in the future.

Apart from these efforts to prevent quality problems at its suppliers, Heavy Truck Co's management feels that it also should put efforts in its capabilities to respond to quality problems that emerge. Once a quality problem shows up during testing or while a truck is in use by a customer, Heavy Truck Co should be able to pinpoint the source of the problem quickly in order to come up with a solution and to identify other trucks that may suffer from the same defect. To improve the management of the whole production process, Heavy Truck Co's managers feel that they need to invest in traceability. Traceability means, on the one hand, that all tasks that have been completed can be traced back to the individual Heavy Truck Co employee, but, on the other hand, it also means that each component can be traced back to a supplier. The latter aspect of traceability is currently not well developed at Heavy Truck Co. If it turns out that a supplier has dispatched malfunctioning parts to Heavy Truck Co, then there currently are three scenarios that can happen:

1. If Heavy Truck Co knows the parts are broken before it uses them, they can be kept out of the production process.

2. If the parts have recently been used for assembly, Heavy Truck Co may be able to pinpoint the trucks that have the faulty parts in them.

3. If the parts have been used months or even years ago, Heavy Truck Co will have a hard time determining in which trucks they have been used.

The final scenario is of course a worrying prospect. If Heavy Truck Co is unable to determine the trucks that contain the faulty components, the only thing that it can do is to recall all trucks from a certain age to the dealerships, which is very costly and inefficient. Therefore, Heavy Truck Co is now in the process of demanding traceability from its suppliers. Heavy Truck Co's suppliers should record each part that is shipped to Heavy Truck Co and attach a unique product code to it, which Heavy Truck Co can use to record which part is used in which truck. By doing so, a part can be traced from the final customer towards the supplier, and the other way around.

One of the reasons why it has until now been difficult for the assembly department to expand traceability to the suppliers is the department's relatively isolated position with respect to suppliers and customers. The assembly department does not have direct contact with suppliers because the contracts for the supply of components are negotiated by a separate purchasing department within Heavy Truck Co's parent organisation, with input from Heavy Truck Co's own procurement department. The parent's purchasing department may have different interests than Heavy Truck Co's assembly department (e.g. a focus on costs instead of traceability).

5.6 The Supplier's Perspective

The interviews with the management of Heavy Truck Co have shown that the importance and responsibilities of suppliers have increased. Modular sourcing of car components has resulted in a need for more sophisticated suppliers and also in a longer supply chain. For the quality of the final product it is essential that Heavy Truck Co manages this supply chain to maximum effect. Apart from the view of Heavy Truck Co's managers on the way they manage the supply chain, it is important to understand the perceptions of their first tier suppliers, which are the other parties in these dyadic relationships. Therefore, this section deals with the views of three suppliers about the changes that have taken place over the last ten years in their relationship with Heavy Truck Co. These suppliers have been selected by the quality manager of Heavy Truck Co on the basis of their importance in terms of the components they supply, and on the impact these components have on the final product.

5.6.1 Supplier 1

Supplier 1 is a production location that belongs to a group of similar plants in various European countries. The whole group is owned by a European investment firm, which is mainly concerned with the financial returns of the plants and not so much with operational processes and developments.

The products that supplier 1 manufactures are cast aluminium engine components, mainly oil sumps. Supplier 1 has been manufacturing these oil sumps for years, both for Heavy Truck Co and for other car and truck manufacturers. The plant is located about 40 kilometres away from the Heavy Truck Co plant.

The oil sumps are available in few variants, which makes the production processes quite stable. Different customers design their engines differently, and therefore the design of the oil sumps differs per customer. However, within each engine design the oil sumps are all identical.

One of the reasons why processes at supplier 1 have remained stable over time, is the fact that this supplier did not make the switch towards modular assembly. The car and truck manufacturers were looking for suppliers that would take up a larger share of the engine assembly, but supplier 1 did not fulfil that role. Therefore, other suppliers have taken their chance and have started assembling engine modules for car and truck manufacturers. Consequently, the customers of supplier 1 have changed from car and truck manufacturers (during the 1990s), towards module suppliers (since 2000). Supplier 1 has become a second or even third tier supplier, which the quality manager of supplier 1 did not seem to regret. He explained that:

> *"In most cases very little has changed. We are still making the same supplies, but we only have to deliver them to a different address."*

Heavy Truck Co has not made the switch towards modular sourcing of oil sumps and related parts. The volume of supplies that Heavy Truck Co procures is such that it is not an interesting contract for most module suppliers. Therefore, the relation between Heavy Truck Co and supplier 1 has not changed.

In terms of quality management, supplier 1 has not many formal systems in place. The organisation is ISO/TS 16949 certified because this is required by most customers. Even though Heavy Truck Co has requested supplier 1 to use Six Sigma, it does not plan to do so. On the one hand, this is an indication of the power that Heavy Truck Co has over this supplier, but on the other hand it also says something about the supplier 1's perceptions of the quality policies at car and truck manufacturers. The quality manager of supplier 1 pointed out that:

> *"Customers are constantly talking about quality, while in practice the difference in quality performance between customers and suppliers is large."*

However, he could not present facts that support his feelings of superior quality performance at suppliers like supplier 1. The quality maturity of supplier 1 actually appeared to be rather low. The quality manager is convinced that his organisation constantly improves, but it is considered too much of an effort to document improvement activities and their results. This lack of documentation also makes it difficult to find out if an increase in the number of complaints about defects is the result of an actual increase in the number of defects, or a result of more critical customers. Nonetheless, the quality manager appeared to have no doubts:

> *"It seems as though more mistakes are being made, but the real cause is the fact that customers are becoming more critical."*

However, the quality manager acknowledges that the organisation could improve if more data were collected in a systematic way. The current approach to defects is a clear example because it is relatively easy to conceal defects, as indicated by the quality manager:

> *"When aluminium is cast, air may get trapped in the die and result in a defect product. However, when this is found to be the case, we can simply melt the aluminium again and reuse it."*

Still, costs have been made for these products, so this clearly provides an opportunity to reduce costs and improve profitability. The quality manager acknowledges this and also feels the pressure to improve processes. Contracts between supplier 1 and its customers usually demand supplier 1 to lower the price of its products by a certain percentage per year. The logic behind this is that suppliers should improve their processes over time, and therefore their costs will reduce. However, supplier 1 is not capable of reducing its costs to the extent that they offset the yearly price reductions. The quality manager pointed out that:

> *"If at the start of the year we receive a letter from a customer to remind us that we should lower our price with 3%, we will typically have been able to lower our costs with 1%, so the other 2% will reduce our profit margin."*

The quality manager indicated that design changes can significantly lower the number of defects and thereby reduce costs for supplier 1. Some customers do not allow supplier 1 to have any say in the design of the products, but Heavy Truck Co is not one of them. Heavy Truck Co involves supplier 1 early on in the product development process and will take supplier 1's comments and suggestions seriously. According to the quality manager of supplier 1, Heavy Truck Co also sticks to a strict product planning and, consequently, will have arranged everything before the start of production.

5.6.2 Supplier 2

Supplier 2 is an independent supplier of gears and drive shaft components. Its most important products are gears for diesel engines, which is also what it supplies to Heavy Truck Co. Supplier 2 has many customers in the heavy truck industry, but gradually the importance of the passenger car industry is increasing. Supplier 2 has been active in this business for more than three decades. Most of its customers are truck and car manufacturers but it also does some manufacturing for first tier automotive suppliers. The plant of supplier 2 that manufactures for Heavy Truck Co is at the same site as the headquarters of supplier 2, which is situated about 100 kilometres away from Heavy Truck Co. Apart from this plant, supplier 2 has two more plants in another country, which makes supplier 2 a small first tier supplier. Supplier 2 would rather become a second tier supplier because it feels that it is too small to be a first tier supplier. However, many truck and car manufacturers still treat gears as a standard high-volume component, which is not often integrated in a module. So, manufacturers buy the gears directly from supplier 2.

Gears are a growth market because the trend of more powerful engines means that belts and even chains are not strong enough to connect different parts of the drive train. Therefore, gears are currently the only efficient solution. The heavy truck industry has had this problem for years because of the large forces in the drive train. However, the passenger car industry is now also moving in this direction, which will mean a significant increase in demand for gears.

Gears are standard products, so there is not much variety within a certain type of gear. However, between different types of gears there are many differences because gears for different purposes can be very different from each other. In practice, not many different types of gears are in production at the same time, because the nature of the products is such that they should be manufactured in batches. To operate efficiently, supplier 2 should manufacture the gears in batches that large compared to the demand of most customers. Therefore, supplier 2 sets up its equipment for one product and then produces enough gears for two to three weeks' demand. These gears are stored in a warehouse and shipped to the customer in small shipments. Meanwhile, the plant starts assembling gears of another type. So, basically the production approach resembles the traditional mass production (see Ford, 1926) with storage in warehouses. This is not in line with the Just-In-Time principles, even though the gears are sent to the customer in small shipments. The sales manager of supplier 2 pointed out that:

> *"The Just-In-Time principles are very strict at the truck and car manufacturers, but further up the supply chain these principles weaken significantly, because many suppliers keep products in stock"*

In terms of quality management systems, supplier 2 also relies on traditional tools and techniques. The main quality system in use is still Statistical Process Control (see Shewhart, 1931), and the quality manager of supplier 2 cannot see any added value in newer systems like Six Sigma. The quality manager claimed:

> *"Six Sigma is exactly the same as the Statistical Process Control of fifteen years ago."*

The plant is ISO/TS 16949 (see ISO, 2002) and ISO 14001 (see ISO, 2004) certified because these are standard requirements to supply car and truck manufacturers. Other than that, the quality manager feels no need to implement specific quality management systems. He explained that:

> *"If an organisation has proper management systems in place, it should not be necessary to have separate quality management systems as well."*

This attitude towards quality management systems results from the belief that, regardless of these systems, it is in the end the employee who makes the difference between a good product and a defect product.

Nevertheless, today many customers demand from supplier 2 that it sticks to a number of systems, like the ISO systems. Some customers even have their own systems, and audit the processes of supplier 2 to see if they are in line with these systems. Until now this has not been a problem for supplier 2.

Supplier 2 feels that they have to live up to increasingly tough contracts. It is normal practice for car and truck manufacturers to demand yearly price reductions of between 2% and 5%. However, some customers currently demand reductions of more than 10% per year, which means a reduction of more than 40% over the whole life cycle of a product. Consequently, supplier 2 needs to improve processes continuously. However, the managers of supplier 2 pointed out that there can be many reasons why the agreed price reductions should not take place, for example, price increases of raw materials and customers that did not live up to their part of the agreements. Yet, the trend of increasingly strict contracts continues for supplier 2, which are not very pleasant conditions to work with.

The approach of Heavy Truck Co towards supplier 2 is completely different. Supplier 2 has manufactured gears for Heavy Truck Co for many years, and it regards Heavy Truck Co as an important customer. Not so much for the volume of supplies that Heavy Truck Co procures (it is not a top-five customer in terms of turnover), but for the way in which Heavy Truck Co allows supplier 2 to develop and implement its expertise. Heavy Truck Co will always involve supplier 2 at an early stage in product development projects, to hear its opinion about the manufacturability of Heavy Truck Co's ideas. The relationship between supplier 2 and Heavy Truck Co has been a pleasant one for many years, and supplier 2 feels that it is treated as a trusted partner.

5.6.3 Supplier 3

Supplier 3 is specialised in hydraulic systems for various industries (e.g. automotive, maritime and agriculture). For the truck and car industry, supplier 3 mostly assembles truck cab tilt systems and electro-hydraulic systems to operate the roof of convertible cars.

The plant of supplier 3 that supplies Heavy Truck Co is a production location of a global manufacturer of tools, supplies and engineered solutions. Supplier 3 has been operating in the automotive industry for more than three decades, and Heavy Truck Co has been a customer from the start. The plant is located about 100 kilometres away from Heavy Truck Co. Twice per week supplier 3 ships cab tilt systems to Heavy Truck Co, which it calls Just-In-Time delivery. These cab tilt systems consist of cylinders, pumps, latches, hose assemblies, and some smaller parts for installation and operations of the whole system.

The cab tilt systems are specifically designed for each truck type. A set of technical variables determines the kind of system that is necessary. The most important technical variables are the weight of the cab, the point of gravity, and the positioning of the cylinders in the cab design. On the basis of these data, supplier 3 will design a system that is capable of tilting the cab. Once the system has been developed and tested, it is put in production. So, supplier 3 will then assemble a whole series of identical systems for that truck type. Consequently, product variety is very limited because the cab tilt systems only differ for different truck types and not for each individual truck. Therefore, there is no need for supplier 3 to deliver its systems in a specific sequence to Heavy Truck Co.

During the last couple of years, the major growth market for supplier 3 has been the convertible passenger car market. However, during the same period of time supplier 3 has gradually shifted from the first tier to the second tier of suppliers. Several suppliers have transformed into specialised assemblers of convertible roofs, and most car manufacturers make use of their expertise.

For truck manufacturers, supplier 3 is still a first tier supplier. Only two suppliers assemble cab tilt systems, so truck manufacturers have not many options to choose from. The specialised nature of the products, combined with few players in the market, mean that most customers from the truck industry rely on supplier 3 for the required knowledge about cab tilt systems. The sales manager pointed out that:

> *"We are typically involved in product development projects at an early stage, because of the specific knowledge that is necessary to develop cab tilt systems."*

Heavy Truck Co is a customer that makes sure that supplier 3 is involved very early. This is appreciated by supplier 3 because it allows the engineers to develop a good system that is not restricted by a completely finalised cab design.

Supplier 3 applies several quality management approaches, systems and tools:

- It is ISO/TS 16949 certified
- It makes use of lean concepts, such as Kaizen, Just-In-Time and Kanban (see Lu, 1989)
- It makes use of Six Sigma improvement projects
- It has established a system to trace back final products to individual employees, as well as to its own suppliers.

An important quality management development in recent years has been the implementation of single piece flow (see Womack and Jones, 1996). The sales manager explained this approach:

> *"Currently, only one person is responsible for the whole manufacturing process of one product, while in the past many employees would share that responsibility."*

This approach has improved the commitment to quality in the organisation, especially in combination with the system that enables supplier 3 to trace back defect products to individual employees.

Most quality initiatives have been implemented because of supplier 3's drive for improvement. However, Six Sigma has been implemented because Heavy Truck Co demands it.

Poor quality is costly for supplier 3 because contracts allow customers to charge money for costs and fines. However, to reduce financial risks, supplier 3 demands during contract negotiations that customers stick to certain rules as well. The sales manager gave the following example:

> *"We demand a minimum to the volume of supplies that customers will order from us, as well as compensation for labour costs when our employees have to disassemble defect components from trucks and install new ones."*

Supplier 3 appreciates that contracts with Heavy Truck Co are not that strict.

5.7 Discussion of Findings

Heavy Truck Co has traditionally been an organisation that offers a large number of product variants. However, the extent to which customers actually choose a truck that closely matches their needs has increased over the years. Therefore, Heavy Truck Co now assembles a wider variety of trucks than in the past.

A truck is a vehicle that is bought and operated for rational reasons. Customers need trucks for specific tasks, and buying a truck is seen as an investment for several years to come. Therefore, there is not much pressure from the market to reduce the life cycles of heavy truck models. Still, regulatory changes (e.g. more demanding emissions and safety rules) lead to shorter life cycles of Heavy Truck Co’s truck models.

As a result of these developments, manufacturing complexity has increased at Heavy Truck Co. To cope with this, Heavy Truck Co tries to make key processes man independent (i.e. using poka yoke systems and automated quality checks), in order to reduce human mistakes. However, at the same time, the role of the shop floor employees in problem solving and improvement activities has become more important. So, there does not appear to be a trade off between man and machine, but instead they are complimentary to each other.

Outsourcing of production by Heavy Truck Co has increased significantly over the last decade, and so has the role of suppliers in the design process of new products. As an increasing share of the manufacturing and design processes are outsourced, the influence of suppliers on the quality of the final product increases as well. Therefore, managing the supply chain will become increasingly important. Heavy Truck Co’s management acknowledges this, and has invested in an assessment system (i.e. the supplier readiness reviews) that examines the extent to which suppliers are capable of delivering components in the required quantity and quality. Together with the shift to modular sourcing and the need to manage second and third tier suppliers, this has meant that Heavy Truck Co’s suppliers have had to improve their organisational capabilities. Since many of the existing suppliers were unable to do so, the number of first tier suppliers has more than halved over the last decade, from 900 to less than 450.

The way Heavy Truck Co looks at trucks has also changed over time. In the past trucks were built solely for doing the tasks they were designed for, however, gradually the comfort of the driver/operator of the truck has become more important. A future aim of Heavy Truck Co is to deliver trucks that have the same high-quality finish as passenger cars. In line with this development, Heavy Truck Co has shifted its design focus. Traditionally, Heavy Truck Co designed its trucks for functionality, while currently suppliers are involved in the design process to improve the quality of the final product. At the same time, regulatory demands for lower emissions and safer trucks influence the design processes as well. However, for the future Heavy Truck Co expects regulatory demands to have an even stronger influence on the design processes, because legislation will demand that manufacturers take care of recycling trucks they manufactured in the past.

The mentioned developments are summarised in table 5.3, where each row indicates one development from past, via present, to future.

Table 5.3: Developments over time at Heavy Truck Co

Past	Present	Future
▪ Potentially many product variants	▪ Actually many product variants	▪ Actually many product variants
▪ Long product life cycles	▪ Shorter product life cycles because of regulatory demands	▪ Shorter product life cycles because of regulatory demands
▪ Production and development in-house	▪ Production to a large extent outsourced	▪ Production and development to a large extent outsourced
▪ Rational product focus	▪ Rational focus and attention to the comfort of the driver/user	▪ Trucks will have the same high-quality finish as passenger cars
▪ Design for functionality	▪ Design for quality	▪ Design for recycling

The way Heavy Truck Co manages the quality of its products and processes has changed over the years, with the following being the major changes identified:

- The design of new truck models and components used to be done completely in-house without involvement of other parties. However, over time Heavy Truck Co has learnt that many quality problems resulted from the design of its trucks. Therefore, Heavy Truck Co has started to involve its suppliers in the design process, in order to prevent quality problems from occurring.

- In the past, Heavy Truck Co had no specific strategy for the balance between manual labour and automation/robotics. However, as manufacturing complexity increased, employees would regularly make the same mistakes. Therefore, Heavy Truck Co has made many key processes to a large extent man independent. This has reduced the number of structural mistakes. On the other hand, the importance of the shop floor employees has increased when it comes to problem solving and improvement activities. The management has learnt that the shop floor employees are much better at solving incidental quality problems because these are usually the result of human behaviour. Consequently, both man and machine play an important role in the management and improvement of quality.

- The complexity of the assembly process has been reduced over time by outsourcing large parts of it to suppliers. Suppliers have switched from manufacturing individual components to assembling complete modules, which consist of several components. By doing so, Heavy Truck Co has, to a large extent, shifted the responsibility for the quality of the trucks to the suppliers, thereby reducing the risk of manufacturing errors inside the Heavy Truck Co plant. A next step in this process will likely be that suppliers also become responsible for installing their modules into the trucks.

- Another quality development, which is related to the previous issue, is the assurance of the quality of procured components. In the distant past, Heavy Truck Co employees would check all incoming supplies. Later, the suppliers had to sign quality agreements with Heavy Truck Co, in which they promised to deliver components of the right quality (by means of process management and quality testing). However, Heavy Truck Co's management has realised that even these quality agreements are not enough, because suppliers should also be able to deliver components in the volumes that Heavy Truck Co needs. Therefore, Heavy Truck Co currently undertakes supplier readiness reviews, which assess suppliers on their flexibility to assemble components in the required quantities, while still retaining high quality levels.

- The quality improvement approach at Heavy Truck Co used to be ad hoc. Anybody in the organisation could come up with ideas for improvements, and the ones that the management liked would be implemented. Currently, Heavy Truck Co is using a much more sophisticated improvement approach, which is built upon the Six Sigma methodology. However, the improvements realised with this approach are very much costs focused, because all current Six Sigma projects should lead to significant costs reductions. Future improvement projects are expected to focus more on soft savings that can be realised by quality improvements during the design and development stages of a truck.

- Today, as well as in the past, quality defects can not always be traced back to individual employees or shipments of supplies. Consequently, Heavy Truck Co may have to recall a large number of trucks if one or more trucks are found to have a structural defect. Given the consequences that a product recall may have in terms of financial costs, as well as damage to Heavy Truck Co's reputation, it is important that all truck components can be traced back to individual employees and shipments of supplies. In the near future, Heavy Truck Co will realise such a traceability system.

- Heavy Truck Co makes use of an assembly manual for each engine that is produced. This manual contains an overview of all tasks that need to be completed on this engine by the different production cells on the shop floor. In the past, this manual would contain an elaborate check list with many checks for each employee. Heavy Truck Co has found out that this does not work well because employees will tick all boxes before they even start working on the engine. Currently, Heavy Truck Co uses a much shorter check list, which only contains the most relevant checks. For the future, Heavy Truck Co wants to develop an electronic version of the assembly manual, which will make it possible to warn employees on digital screens if critical or exceptional tasks need to be done for this engine. Moreover, a digital manual will allow last minute changes by the customer, and it allows for tracking and tracing of exactly when a certain task has been completed on the engine.

The mentioned developments in the quality management systems are summarised in table 5.4, where each row indicates one development from past, via present, to future.

Table 5.4: Developments in quality management systems at Heavy Truck Co

Past	Present	Future
▪ In-house design	▪ Supplier involvement in design process	▪ Supplier involvement in design process
▪ No specific strategy for balance between man and machine	▪ Processes man independent, while shop floor employees are key in problem solving and improvements	▪ Processes man independent, while shop floor employees are key in problem solving and improvements
▪ Single component sourcing	▪ Modular sourcing	▪ Suppliers assemble and install components in the trucks
▪ At first inspection of supplies, later on quality agreements	▪ Supplier readiness reviews	▪ Supplier readiness reviews
▪ Ad hoc improvements	▪ Structured Six Sigma approach	▪ Improvement of designs
▪ Recall of all trucks that may have a defect	▪ Recall of all trucks that may have a defect	▪ Traceability of tasks and components
▪ Engine assembly manual with long check list	▪ Engine assembly manual with reduced check list	▪ Electronic manual that warns for critical tasks, allows for last minute changes, and enables tracking and tracing

5.8 Summary

This chapter has presented and discussed the case of Heavy Truck Co. First, the relevance of this case for the two trends of increasing product variety and shortening product life cycles has been discussed.

Relevant developments that have taken place at Heavy Truck Co over the last decade have been described, as well as the view of three important first tier suppliers of Heavy Truck Co.

The most important developments in the quality management systems of Heavy Truck Co have been summarised and discussed. These form the basis of the comparative analysis of all three cases in chapter 8, which also contains an interpretation of the developments at the case companies from the perspective of Simons' four levers of control model.

6 Case Study 2: Small Car Co

6.1 Introduction

This chapter describes case company 2, which is designated as Small Car Co. The general characteristics of Small Car Co are presented in table 6.1. Small Car Co is a contract manufacturer that produces cars for car manufacturers. The company is owned by a global car manufacturer but is treated as an independent profit unit. Small Car Co manufactures two car models, which will be referred to in this thesis as Model One and Model Two, for two different global car manufacturers. These two models have been introduced in 2004, so they are both at the beginning of their life cycles. Both models share the same platform and are assembled on one assembly line. During the early years the demand for these cars was disappointing and as a result production numbers and the number of employees have gradually been reduced (see table 6.1). Prior to the production of the current two car models, Small Car Co has been assembling other cars. Some of these were for the same brand as one of the current two models, while others were for different brands.

The methodology of the research has been described in detail in chapter 4. Therefore, this chapter only describes the data that have been collected from the case company by means of interviews, document study, factory tours and feedback meetings. Table 6.2 provides an overview of all interviews and factory tours that have taken place at Small Car Co and its suppliers. During the interviews, the managers of Small Car Co and its suppliers have presented their views and opinions, however, whenever possible these views have been supported by relevant facts. Moreover, the data about Small Car Co reported in this chapter are not just the quality manager's views, because all issues presented have been raised by at least two Small Car Co managers. In addition, factory tours and document studies have been used to support the information from the interviews. These forms of cross examination (i.e. triangulation) of the case study are intended to improve the reliability of the results. Direct quotes are used throughout the text to support the statements made. If an interview has been conducted in another language than English, the presented quotes are a translation of the original quotes, agreed with a native English speaker who is also fluent in the language of the interview.

Following the introduction, the relevance of the case company in relation to the topic and aims of this research is explained. The data from the case company are then presented to explain the relevant developments that have taken place at the case company over the last ten years. These data are structured along the three building blocks of quality management (i.e. customer focus, reduction of variation in organisational processes, and continuous improvement), which have been explained and discussed in chapter 2. Where relevant, references to available literature are made in the case study data. Following the examination of the case company, an examination of three of its first tier suppliers is presented. In the final section of this chapter the findings from the entire case study are discussed and interpreted.

The data description only contains relevant facts from the case study company and no comparative analysis with the other case companies is undertaken at this stage of the research (the analysis of all three cases is presented in chapter 8). The data are also not interpreted in terms of Simons' four levers of control model, since this will also be dealt with in chapter 8.

Table 6.1: Characteristics of Small Car Co

	Small Car Co
Market segment	Small cars
Type of production	Contract manufacturing
Annual production volume	210,000[1]
Number of different models assembled	2
Number of employees	4,300[2]
Factory location	Western Europe
Number of first tier suppliers	250
Major suppliers on-site in supplier park	Yes

1: Has been reduced during the years 2004 and 2005 to 115,000 cars
2: Has been reduced during the years 2004 and 2005 to 3,000 employees

Table 6.2: Interviews at Small Car Co and its suppliers

Company	Interviewee(s) / *Activity*	Date
Small Car Co	Quality manager	4 March 2004
Small Car Co	*Plant tour*	4 March 2004
Small Car Co	Quality manager	14 April 2004
Small Car Co	*Plant tour*	14 April 2004
Small Car Co	Production manager	19 April 2004
Small Car Co	Logistics manager	26 April 2004
Small Car Co	Human resources manager	1 June 2004
Small Car Co	Supply chain manager	14 July 2004
Small Car Co	Quality manager; Logistics manager	25 November 2004
Supplier 1	Quality manager	26 April 2005
Supplier 1	*Plant tour*	26 April 2005
Supplier 2	Quality manager; Continuous improvement manager	26 April 2005
Supplier 2	*Plant tour*	26 April 2005
Supplier 3	Quality manager	14 June 2005

6.2 Relevance of Small Car Co for the Research

In this section the research context of Small Car Co is described. The extent to which increasing product variety and shortening product life cycles play a role for Small Car Co is discussed first. Thereafter, the importance of quality management for Small Car Co is explained.

6.2.1 Product Variety and Life Cycles

Small Car Co produces a large variety of cars with the current Model One and Model Two. A total of 100,000 different variants are possible, which is much more than for any previous car model assembled by Small Car Co. The cars can differ from each other in many ways (e.g. chassis, power train, exterior trim, interior trim and electrics/electronics).

Apart from the increase in product variety, life cycles of Small Car Co's car models are getting shorter. The production manager commented:

> *"Previous car models that we manufactured had a life cycle of seven to nine years and some models even ten years, while we expect a life cycle of only five to six years for the current two models."*

This is in line with the general industry trend of shortening product life cycles (see e.g. Von Corswant and Fredriksson, 2002).

These two trends present problems to Small Car Co. Increasing product variety complicates production processes because employees need to be multi skilled, automated systems need to become more flexible, and suppliers need to increase their capabilities. Moreover, combining a certain set of options into one car, may lead to unanticipated problems, like manufacturability problems and compatibility problems of electronic components. The shortening of product life cycles means that both quality and efficiency should be high straight from the start of the life cycle. The production manager pointed out that:

> *"In today's environment the start up of a new car model is not acceptable anymore as an excuse for poor efficiency performance. Directly from the start of the production of a new car model efficiency should be constantly improved."*

This is in stark contrast to the past when Small Car Co only worried about quality during the start up phase of a new car model. To be able to improve efficiency from the outset, production employees are necessary to realise process improvements in the daily process operations. However, at the same time these employees are also necessary to facilitate the start up process. Therefore, demands on employees are high during the start up phase.

6.2.2 Importance of Quality Management

The interviews with Small Car Co's managers indicated that quality management is very important to the company, with the following being typical:

- A small defect in some part of the production process that remains undetected for a short time, results in a large number of defect cars that cannot be sold. Therefore, preventing quality problems avoids high unexpected costs.

- Small Car Co copes with the cyclic demand for cars by adding or standing down production shifts. However, this leads to changes in the composition of self-managing teams, which can impact product quality because the employees are used to their team members and any changes in the team affect working behaviour and work patterns.

- As a result of price pressure in the market, Small Car Co has a constant incentive to reduce costs. One way to realise this is by reducing quality costs (see for example Dale and Plunkett, 1999; Campanella, 1999). Several years ago it was acceptable for new car models that only 20% of cars produced were correct when they came off the assembly line (i.e. first-time correct). However, this means that 80% of cars produced had flaws of some kind and therefore needed rework. Currently, Small Car Co has set a target of 95% first-time correct after one year of production of Model One and Model Two. This would mean a significant cost reduction for Small Car Co. The link between quality and efficiency is considered by the management team as the only way to excel as a plant. Efficiency is absolutely necessary to survive, but low quality reduces efficiency because of scrap and rework. Therefore, high quality is necessary to reduce scrap and rework and thereby improve efficiency. This line of thinking is in accordance with the Deming's approach to quality management (see for example Deming, 1982; Deming, 1986).

- The application of Just-In-Time (JIT) and Just-In-Sequence (JIS) (see for example Hay, 1988) delivery of supplies means there is no room for quality problems because they would disturb not only the processes inside the Small Car Co plant but also the logistics between the suppliers and Small Car Co. If the production line in the Small Car Co plant stops, all supplies that are on route to Small Car Co just continue normally. This means that Small Car Co will have many supplies in transit that it cannot use at that moment. Given that Small Car Co has eliminated its warehouse capacity this would lead to storage problems.

- Apart from these operational consequences, stopping the production line also has major financial consequences because of the way in which Small Car Co gets paid for the cars it manufactures. Small Car Co gets paid a fixed percentage of the value of every car it produces, which means that it receives 12% to 14% of a car's value. So, Small Car Co's added value is only in manufacturing and no production means no revenues. Every minute the production line is idle, Small Car Co loses 2,000 Euros, therefore Small Car Co acts quickly in case of problems with production. If a supply is defective, Small Car Co immediately sends the supplier an e-mail with photographs of the problem. At the same time Small Car Co tries to solve the problem at its production line. The supplier has to react immediately and has to come to the Small Car Co plant to solve the problem. In some cases suppliers have outsourced such problem solving to specialised local firms to normalise the situation as soon as possible.

This important role that quality management currently has at Small Car Co, is also supported by the developments that have taken place at the quality department. Prior to 1995 the quality function at Small Car Co had been downsized and decentralised, so every department had its own quality function. As a result, the authority of the quality department had diminished because line managers were not obliged to cooperate with the quality department. However, in 2000, the quality department has again been centralised, increasing its strategic importance and its abilities to communicate quickly throughout the organisation about quality problem.

During the interviews, Small Car Co's managers indicated that the management of quality and the speed with which that has to take place have changed tremendously over the last ten years. In today's environment it is not acceptable to take a long time to solve a quality problem. Given this enormous importance of speed in quality management, other quality tools and systems are needed. Consequently, the tools and systems have developed rapidly in recent years. The use of computers, online systems, simulation models etc. has increased speed enormously, and will continue to do so in the future.

In addition to the increased speed with which quality problems need to be solved, the complexity of car manufacturing has increased for Small Car Co, which compounds the difficulty in solving quality problems. The ways in which manufacturing complexity has increased over the last decade are detailed below:

- Firstly, the complexity of the car itself has increased. The most important factors in relation to this have been car electronics and software. This increase in complexity is felt by many car manufacturers because of the increase in electronics and software related quality issues, which are responsible for a large share of today's car defects and dissatisfied customers (Chappell, 2005).

- Secondly, the complexity of managing the supply chain has increased, both in terms of the complexity of supplies as well as the complexity of logistics. More production is now outsourced to suppliers than in the past (the production time inside the Small Car Co plant has been reduced to a mere 13 hours per car). The supplies have become larger and more complex and suppliers are required to bear more responsibilities. At the same time, the complexity of logistics has increased because suppliers have moved to more distant locations (i.e. Eastern Europe, Asia) to benefit from low wage economies. Consequently, in the case of quality problems the response time of these suppliers is relatively long. If a defect part is found by Small Car Co, it will probably be an indication that in the current and future delivered batches of supplies, many more defect parts can be expected. Moreover, it will take a long time to fix the problem and deliver good parts to Small Car Co. The managers were agreed that this is a serious issue, especially because many low-wage countries are relatively unsophisticated in terms of their quality maturity.

- Thirdly, the complexity of product development has increased. It was clear to all managers interviewed that development is not anymore something that Small Car Co can do alone. These days, car manufacturers need to involve many suppliers and technology partners to help them with the development of new products and accessories. Product development has become so complex that the suppliers are the only true experts for many car components. Car manufacturers need to rely on the knowledge and experience of their suppliers. Product development projects quite often involve parties from all over the world, which leads to communication problems and time lags. So, the risk of not meeting development deadlines is increasing because too much is not under the direct control of the car manufacturers.

Summarising the above arguments, it can be concluded that the management and improvement of quality is essential to Small Car Co. If quality is not under control, Small Car Co's operations will be in chaos and the future of the organisation will be under threat since quality is essential to make a profit. All the developments and issues described in this section indicate that today quality is even more important to Small Car Co than ten years ago. Therefore, the following sections will examine how the management and improvement of quality have changed over the last ten years at Small Car Co in order to cope with the current business environment.

6.3 Customer Focus

In this section Small Car Co's focus on the customer is discussed. Relevant issues for Small Car Co are variation in customer demand (i.e. when do they want to have a new car?) and customer expectations (i.e. what do they expect from their new car?). These issues are dealt with in the remainder of this section.

6.3.1 Variation in Customer Demand

Today, Small Car Co builds cars to customer order whereas it previously built them to production plan. With the current climate of increasing product variety, it has become impossible to build cars to plan. The variety of cars is so high that customers are very likely to order a car that is not in stock somewhere in the supply chain. Moreover, the shortening product life cycles of cars also makes it more risky to build to plan.

Building to customer order means that the production of a car will only start after a customer places an order. However, customer demand is not stable over time, which impacts production processes at Small Car Co. Customer demand fluctuates for two reasons:

1. Seasonal effects result in fluctuating demand because demand for certain types of vehicles is directly linked to certain seasons (e.g. customers only buy convertible cars when the weather is warm). However, even for more mainstream car models the demand is not constant because of the money that customers have available. For example, after consumers have spent their money on a holiday they do not have money left for a new car, which results in low demand in the post summer period.

2. The life cycle of the car model. When a car model has just been introduced, demand for it is high, while at the end of the life cycle it is much lower.

To make optimal use of capital goods in such an environment of unstable demand requires the flexible use of labour. Small Car Co switches for example from two to three production shifts if demand increases (and from three to two again if demand decreases). Small Car Co also has the option to let its employees work on Saturdays, or to send its employees home a certain number of days per year without having to pay them a salary for those days.

However, these measures are not ideal for Small Car Co. Adding or standing down production shifts results in changes in the composition of self-managing teams, which can impact product quality. Moreover, adding or standing down production shifts is not enough to compensate for life cycle effects. The human resources manager indicated that:

> *"At the beginning of the life cycle our employees can never work enough hours, while at the end of the life cycle a large number of employees could best be sent home."*

To cope with these long term effects it would be ideal for a car manufacturer to have a range of car models that are in a different stage of their life cycle. So, one car model should be at the beginning, while another one should be at the end. In such a situation high demand for one car model is offset by low demand for the other and over time total production can be kept relatively stable.

6.3.2 Customer Expectations

At the end of the 1980s, discussions were held at Small Car Co about the ‘person of the future’. Small Car Co realised then that it would not be possible in the future to serve all customers with the same mass produced car. One-on-one relations would have to be created with customers who would by then have a strong sense of individualism. Therefore, in those years there was already a feeling that a variety of cars would have to be produced in the future. This was called ‘customer oriented production’, which meant that the production planning of the build-to-plan strategy of those days was adapted to the wishes of individual customers (within the limits of the possibilities of processes). This customer oriented production philosophy was never fully implemented during those years. However, it did lead to a permanent change from past behaviour, in the sense that the expectations of individual customers have become a more important factor for Small Car Co.

To pay more explicit attention to customer perceptions of the cars, eight to ten cars each day are put aside and completely checked by Small Car Co’s quality department staff during a customer audit. No cars are disassembled during these audits because they only serve to represent the customer’s perception of the final product. Any flaw that is found is recorded and analysed.

During customer satisfaction tests, the car is judged from a customer perspective to assess if the customer is likely to be satisfied with this car or not. All comments from the customer satisfaction test are translated into checklists that will be used during the production process to prevent problems from arising again in the future. There are two important parts in this customer satisfaction test:

1. Technical aspects of the car.
2. The paintwork of the car.

During the development of the current Model One and Model Two, the emphasis was not just on customer perceptions in general but more on the perceptions of individual customers. The management of Small Car Co felt that, to fulfil expectations of individual customers, it should be possible for consumers to highly customise their cars. However, to keep costs down, volumes of car components should be high, and it is obvious that these two demands are contrary to each other. To deal with this problem, Small Car Co ensured that some car components were universal between all cars, while other components come in many variants. The quality manager commented that Small Car Co's management believes that:

> *"Only the visible parts of a car are important for the brand image of that car, while the parts that are not visible to the customer are not important for the brand image."*

So, Small Car Co aims to standardise all parts that are invisible to the customer, while at the same time differentiate the visible parts as much as possible between different car models.

6.4 Variation Reduction in Organisational Processes

In this section the developments that have taken place at Small Car Co to control the organisational processes are discussed. The major factor in relation to organisational processes is the risk of poor quality. Relevant processes for Small Car Co are planning, production, purchasing and logistics. These issues are dealt with in the remainder of this section.

6.4.1 Planning Processes

The importance of planning processes has increased tremendously for Small Car Co over the last ten years. During the last decade nearly all slack has been removed from the organisation:

- Buffers between the different parts of the production process have nearly all been removed.
- Floor space used for warehouses has been reduced to the bare minimum.
- Many supplies are delivered in sequence and in small shipments
- Employee numbers have been reduced, and remaining employees are required to do a wider range of tasks.

These changes necessitate Small Car Co to precisely plan the whole production process and everything that has an influence on it. The production manager explained:

> *"If one part of the production process is stopped because of problems, the whole plant will be running idle within ten minutes because there are hardly any buffers in the system."*

The only buffer in Small Car Co's production process, which can contain up to 500 cars, is between the paint shop and final assembly. The major reason for the existence of this buffer is the need to plan the production process and to change the sequence of cars in the production process. This is necessary to balance the workload during the final assembly of the cars. Not all cars require the same amount of work to be done during the final assembly part of the production process. Therefore, the sequence of cars is changed in order to have a balanced mix of labour-intensive and less labour-intensive cars in the final assembly.

Other task related reasons why planning the production process and balancing the workload is now much more important than ten years ago, are the increased complexity of the manufacturing process, as well as stricter legal demands and trade union agreements. The latter mean, for example, that the amount of time an employee can spend on any one task is restricted because of ergonomic reasons. Depending on the task, the employees have to change their task every two or four hours, or daily. The human resources manager explained that:

> *"The need for job rotation coupled with the large variety of car models that go down the same production line, indicates that it is difficult for employees to build up routine and increase efficiency."*

Small Car Co has to take this into account when planning the production process.

Planning already plays a role before the actual production has started. Given the complexities of modern car manufacturing, it is considered important to plan the production of a car when it is still in the design phase. Therefore, design for assembly nowadays receives much more attention than ten years ago. Car manufacturers would in the past come up with a finalised design for a car model and ask Small Car Co to assemble that car. However, nowadays it is common for Small Car Co to be heavily involved in the design and development as soon as it has become clear that Small Car Co has to build the car model. That starts already in an early stage around the computer models. Small Car Co will bring in its experiences from the past because Small Car Co has learned a lot over the years about what can go wrong in production and which are the difficult things to manage. Engineers and designers from the car manufacturers will listen to Small Car Co because they accept Small Car Co's know-how of car manufacturing. Even when new complexities are used for the first time, Small Car Co can help the designers. For example, Small Car Co advised designers on the current trend of mixing plastic and metal components in the exterior trim, which has an effect on part movements since they react differently to temperature changes (e.g. expansion).

Quality has to be built-in into product development projects. This is done for example by having a prototype car body on which all components are installed as for a normal car. From these tests Small Car Co can learn what needs to be changed before the pilot series production begins. This process is done several times and thereby provides Small Car Co with a number of improvement loops before the actual production starts (they do two or three improvement loops within one week). The quality manager explained that:

> *"We have certainly learned from the Japanese during the last decade how to bring down the defects in a new car model from 1,000 to 10 in a very short period of time. While competitors regularly start normal production when there are still hundreds of quality problems to be solved, we will have solved the vast majority during the prototype phase."*

The best employees are involved in this testing process (not only from Small Car Co itself but also from its suppliers) in order to find all potential problems by means of these trials.

At the end of each trial there is a quality meeting at Small Car Co during which checks, audits, measurements, etc. take place. Things that are still wrong have to be improved before the next phase. If a supplier is unable to make improvements within the set timeframe, then it has to present to senior management why the problem is so difficult that it cannot be solved quickly. So, this is a challenging management system because it stimulates suppliers and everyone involved to speed up the improvement processes. Everything is very much time restricted and it is all very well planned. Small Car Co is working with clearly defined quality gates to keep everything under control.

Small Car Co builds all prototypes itself so that it can identify potential problem areas directly. These are manufactured on a regular production line that will also be used later for the normal production. This approach brings better results than building a prototype by hand. Moreover, it is also cheaper to do it in this way, even when taking into account that many parts are coming from suppliers.

Once the prototype phase is finalised and normal production has started, a major role in the planning processes is played by Small Car Co's logistics department. The logistics manager put it this way:

> *"The major role of Small Car Co's logistics department has developed over the last ten years and is now to shelter the production department from external parties."*

There are three major external parties that can influence the production department:

1. The marketing and sales department of the car manufacturers for which Small Car Co assembles cars.

2. The engineering department of the car manufacturers for which Small Car Co assembles cars.

3. Small Car Co's suppliers.

Each of these parties has a different influence on the production department but for each party the logistics department has a mechanism that shelters the production department from it. The structure is as follows:

- The marketing and sales department translates customer demands into orders for Small Car Co's production department. To shelter the production department from direct influence of marketing and sales in the production process, the logistics department translates all requests from marketing and sales into a production planning for the production department. Marketing and sales is Small Car Co's customer and it therefore determines which cars are needed. This demand for cars is the starting point for the production planning, which is made monthly for a year ahead. The planned sequence of cars on the production line that results from this production planning determines the order in which suppliers deliver their supplies to the production line. Therefore, Small Car Co tries to stick to the production planning as much as possible to avoid problems with supplies.

- The engineering department gives engineering orders to the production department. In practice this means that about 8,000 changes per year have to be made by the production department and/or the suppliers to products and processes. To shelter the production department from direct influence of the engineers, the logistics department uses a mechanism which introduces the many engineering changes in a planned and coordinated way.

- Small Car Co's 250 suppliers represent all issues that happen in the supply chain. To prevent problems in the supply chain impacting upon the production department, the logistics department uses a mechanism to plan and manage the flow of goods down the supply chain towards the production line. The logistics department is responsible for ordering the supplies and for the transport from the supplier plant to the production line.

Being a contract manufacturer, Small Car Co has worked for different car manufacturers. All big car manufacturers have their own planning systems and Small Car Co has not been able to persuade them to use a common system. Examples of the differences between planning systems are:

- One car manufacturer uses production planning cycles of four or five weeks, while another uses full months. The problem for Small Car Co is that it has to deal with both planning cycles at the same time.

- Car manufacturers use a long string of digits to represent the specifications of an individual car (e.g. the first digit represents the type of car, the second digit represents the engine type, the third digit represents the gearbox, etc.). Different car manufacturers have different ways of coding cars by means of such strings of digits. Small Car Co needs to understand them all and convert them to a uniform system. This is crucial because these strings of digits are converted to a 'bill of material', which is necessary to determine the supplies that will be needed for an individual car. These bills of material are very complex and consist of approximately 40,000 lines of code per car model. Given that nearly each car has unique specifications it is very important that the material needs are correctly determined in advance.

6.4.2 Production Processes

Over the last ten years, robust design has become much more important. To be able to manufacture cars that come in a total of 100,000 different variants, it is necessary to apply robust design of production processes and products. Every part of the production process that can be kept constant should be embedded in the process. In particular in the physical production process, optimisation is achieved by means of standardisation and the use of robots. No matter what type of car is produced, there are certain aspects that always stay the same. The quality manager gave the following example:

> *"There are critical connections between parts of a car that always need to be bolted together in a certain way. We will not deviate from these standard procedures, no matter what our customers want."*

Over the years Small Car Co has managed to do this task well, therefore it now has more time to focus on the changes that are caused by a specific car variant.

Small Car Co has a down-to-earth approach to the management and improvement of quality, evidenced by the following comment from the quality manager:

> *"We do not have big quality programmes with fashionable names (like Six Sigma), because we feel that we just have to do what needs to be done, which is solving every quality problem that arises."*

However, Small Car Co does use various quality tools and techniques, although these are seen as a normal part of the production process and are therefore not given special labels that make them stand out from other activities. One of these tools and techniques is a poka yoke approach (see Shingo, 1987), which makes it nearly impossible for employees at the production line to make mistakes. Employees who need to use multiple parts during the assembly process can accidentally pick the wrong part. The poka yoke system employed by Small Car Co to prevent these mistakes lights up a light next to the parts box that contains the right part. Small Car Co also has checks and feedback loops built-in into its production line. These checks and feedback loops are direct and fast. An example is the tightening of certain critical bolts, which is done by one employee and immediately checked by the next employee, who should give direct feedback in case of problems. This approach is in line with the 'successive inspection system', as developed by Shingo (1986).

The risk of poor quality has been reduced further in recent years by clearly defining which person or department is responsible for the car at any moment during the production process. The borders between the different parts of the production process are called quality gates. At each gate, quality checks are done to ensure that quality is up to standard. This makes it easier to manage the process because it clarifies at what stage a person or department is responsible for the car. Therefore, it is not possible anymore to avoid responsibility for errors that have been made during the different parts of the process, which would happen regularly in the past.

If quality problems arise in the final product, Small Car Co uses a simple four step process to solve them:

1. Give feedback with respect to the specific problem that has been found.

2. Make sure the customers will not experience any negative effects from this problem.

3. Solve the problem in the production line.

4. Find a structural and long-term solution to the problem.

All quality problems that are found in the final product are reported to the management team during daily meetings in the customer audit department. This procedure makes sure that the responsible people feel the pressure to quickly come up with a solution because they do not want to tell the management that they have not been able to solve the problem. The quality manager indicated that management wants clear answers:

> *"Straightaway, the responsible people should present to the management what exactly went wrong, how this was possible, what is done to solve the problem in the short term, and what structural measures are taken to eliminate the problem for the future."*

If the management is not satisfied with the way the problem has been tackled, it demands that the responsible people explain how the problem will be solved structurally. This is irrespective of whether the responsible people are Small Car Co employees or employees of a supplier because in both cases management demands that it is informed about the measures that are being taken to solve the problem.

Despite Small Car Co's control over the production process and over quality issues that arise, all those managers interviewed were agreed that more is needed to survive over the long term. Both quality and efficiency need to be at a high level to have a future in contract manufacturing. Therefore, Small Car Co needs to operate with at least two production shifts. Once a new car model has been introduced to the market, Small Car Co usually moves after about half a year to three production shifts to satisfy the demand. In the first six months of production the line speed of the production line is gradually increased until it reaches the maximum speed. Thereafter the third production shift is introduced and the speed of the line can be reduced because of the extra capacity from the third shift. It is necessary to reduce the speed of the line somewhat to allow new employees to get used to the production process. Similarly, if Small Car Co goes back from three production shifts to two, the two shifts have to work at first at a higher speed then before, to make up for the lost capacity of the third shift. Once demand has fallen further, the line speed can be reduced for the remaining two production shifts.

The first time Small Car Co went from two to three production shifts, quality demands were compromised in order to attract sufficient new employees. On top of that, too many employees were employed on a temporary basis (i.e. 50% of the employees worked on a temporary contract) and some employees left already after a short time. This resulted in big problems for Small Car Co, threatening its stability and causing many quality problems.

Small Car Co has learnt some important lessons from that experience. Now, when it expands from two to three production shifts, strict quality demands are upheld while recruiting new employees. Also the proportion of employees on a temporary contract is not allowed to exceed 30%. However, the result of these strict demands is that it is more difficult to attract enough new employees. The last time Small Car Co went from two to three production shifts, it had set a target of forty new employees per week, in order to be able to introduce them gradually into the plant and into the autonomous groups. However, Small Car Co regularly fell short of its weekly target because of the stricter demands it now imposes upon itself.

6.4.3 Purchasing Processes

The importance of Small Car Co's supply chain has increased enormously over the last ten years. The increase in outsourcing that has taken place during the last decade means that suppliers play a major role in the quality of Small Car Co's cars. The quality manager claimed that:

> *"The quality of our cars is determined by our suppliers. In fact, all current major quality problems with Model One and Model Two are supplier related. There are virtually no quality problems caused during the manufacturing process within our own plant."*

This is a major risk for Small Car Co and it means that the quality focus needs to shift towards the supply chain and the management of quality at the suppliers. Moreover, Small Car Co needs to take supplier quality already into account during product development. Product development has become so complex that the suppliers are the only real experts for most components of a car. This is not only true for Small Car Co because there is a general trend in the automotive industry of knowledge moving to suppliers (The Economist, 2005). The management of Small Car Co is aware that outsourcing large parts of the production process may mean that Small Car Co loses expertise in certain fields. Recently the share of electronics in the total costs of Small Car Co's cars has risen significantly. Most of these electronics are bought in from suppliers, which makes Small Car Co vulnerable to quality issues in these electronics. The logistics manager explained that:

> *"The knowledge disadvantage that car manufacturers have to suppliers in the field of electronics makes it hard for car manufacturers to communicate with the electronics suppliers. Therefore, it is sometimes felt that car manufacturers should keep certain critical parts of the production process in-house and that car manufacturers should involve themselves in new developments."*

An example of the increased complexity of product development is the development of the instrument panels of Model One and Model Two. The development of the instrument panels involved many engineers from Small Car Co and some 40 suppliers. In addition, the engineering was done in many different parts of the world, while production would take place in Western Europe. Likewise, the purchasing of all the supplies was done from two locations. Therefore, all activities needed to be well organised in order to finish the project before the deadline. However, every day there were communication and interpretation problems. In the end, Small Car Co felt that the only way to solve these problems would be to put all decision makers together in one room to discuss the project face-to-face. Even then, it was still very difficult to have so many different people from many different backgrounds work together in a cross-functional and cross-organisational way on the same project.

Cross-functional teams, which are usually cross-organisational as well, have become much more important at Small Car Co over the last decade as product development projects have become more complex. The supply chain manager pointed out that:

> *"We put lots of efforts in cross-functional teams because they are very important in our processes. Nowadays, training programs for employees pay serious attention to cooperation within cross-functional teams. These teams are not only used during product development but also during normal day-to-day operations."*

High pressure placed upon employees in the automotive industry means that it is important to have reliable people at different positions in the supply chain. Cross-functional teams should consist of people Small Car Co can rely on. Therefore, many suppliers nowadays employ former Small Car Co people. These people know the Small Car Co culture and can communicate well with the people at Small Car Co.

Teams of Small Car Co employees and supplier employees are not the only way in which Small Car Co controls its purchasing processes. Small Car Co also has strict demands regarding the quality systems that suppliers use. These demands are not new to Small Car Co because they have been in use for many years. However, they are still found to be very important for controlling the quality of supplies. For example, all suppliers need to be certified to the QS 9000 or ISO/TS 16949 quality system standards (ISO, 2002). Even though the demand for certification has not changed over the last ten years at Small Car Co, the ISO 9000 series of quality system standards themselves has changed significantly (Van der Wiele et al., 2005). Therefore, the suppliers need to change and improve in order to remain certified. In addition to quality system standards, Small Car Co demands that certain measurements are done by suppliers on the supplies they manufacture and the supplier has to show the results of these measurements to Small Car Co. Employees of Small Car Co also visit the factories of the suppliers when they are working at normal operating speed. These measures are strict and all suppliers need to comply with them to be allowed to work for Small Car Co.

Small Car Co acknowledges the importance of measuring the performance of its suppliers. It uses an external balanced scorecard for this, which measures the performance of existing suppliers on the following criteria:

- Quality
- Costs
- Delivery performance

The developments in computer technology and software that have taken place over the last decade allow Small Car Co to measure and report these criteria on a daily basis. So, the speed with which facts about quality are known to all parties involved has increased enormously, as has the speed with which suppliers have to solve defects. The supply chain manager explained that:

> *"The suppliers can observe their performance online and in real-time via our supplier portal. If a supplier notices a gap between its targets and its actual performance, it is required*

to take action immediately without waiting for us to complain about the poor performance."

Once a month, Small Car Co has an official formal review of the performance of its suppliers to see if they live up to the agreed targets. However, if there are severe problems with a supplier, Small Car Co will of course not wait until this performance review because immediate corrective action has to be taken then.

An ongoing development in recent years is systems integration. An increasing number of parts are sourced in complete modules instead of individual parts. As a result of this modular sourcing trend the number of suppliers to Small Car Co has been reduced. At the time of the study, Small Car Co used 250 suppliers but the management expected this number to reduce in the coming years to about 150 suppliers. This development is in line with survey findings reported by Von Corswant and Fredriksson (2002). However, there are also risks associated with the trend of systems integration. For example, the identity and know-how of cars is increasingly in the hands of the suppliers, while the car manufacturer has simply become an assembler of parts into a final product. An extreme example of this is the relationship between Small Car Co and supplier 2. Supplier 2 manufactures the complete instrument panel for Model One and Model Two. Moreover, the instrument panels are installed in the cars by a robot in Small Car Co's production line without Small Car Co employees' involvement. The result of this form of outsourcing is that Small Car Co has less direct control over the process, but to compensate for this, Small Car Co is involved in the design and development process. However for modular sourcing to be successful, two things are necessary:

1. Suppliers should be capable of delivering complete modules.

2. Small Car Co should have enough expertise (from materials to production techniques and from mechanics to software) to judge the capability of every key supplier to develop and produce to the required standards.

To control quality under these changed circumstances, Small Car Co demands from its first tier suppliers that they accept the second tier suppliers that Small Car Co prescribes. Moreover, Small Car Co will only allow a first tier supplier to deliver a certain set of car components (i.e. the ones that are in the supplier's field of expertise). This approach is necessary because some suppliers overestimate their own capabilities. The quality manager explained that:

> *"In some cases suppliers offered to manage parts of our supply chain for us but in the end they could not deliver what they had promised, which lead to many problems."*

The management of Small Car Co also feels that suppliers which offer manufacturers components that are new to these suppliers, present a risk for the manufacturers. However, when it concerns the components that suppliers have experience with, Small Car Co believes that nowadays suppliers have more knowledge than Small Car Co.

Knowledge about supplies also plays an important role within Small Car Co because there are large differences between the different departments. Small Car Co's purchasing department bears most of the responsibility for suppliers. However, there is no strong link between the purchasing department and the final assembly department. This leads to problems during the production process in the Small Car Co plant. To avoid these problems the final assembly department should be involved in the design process and in negotiations with suppliers. Therefore, cross-functional teams are necessary to address issues from different points of view. However, this means that people from the final assembly department should be part of these teams, which leaves fewer production people to do the actual assembly work. So, the final assembly department as a whole will become less lean, while this is a very important performance criterion. However, if problems are not addressed at an early stage, they will cause problems during the production process and therefore lower the efficiency of the Small Car Co plant. Consequently, there is a tension between trying to be as lean as possible, and preventing problems during the production process that will in the end lower efficiency.

6.4.4 Logistic Processes

Because of the increase in outsourcing that has taken place at Small Car Co over the last decade, logistic processes have become more important. Supplies are increasingly assembled far away from Small Car Co's plant and warehouses have nearly all been closed. Therefore, logistic processes are critical to Small Car Co.

One clear threat for Small Car Co is congestion on European roads. If it becomes more difficult for Small Car Co to have its supplies delivered on time at the plant, processes may be disturbed with consequences for efficiency and therefore profitability of Small Car Co. The risks of disturbances in logistic processes are also increasing because more suppliers move further away from Small Car Co to Eastern European countries. This fear is also felt by other car manufacturers and suppliers who procure from Eastern Europe (Frink, 2006). This raises the question if Small Car Co itself can remain in Western Europe. The logistics manager commented that:

> *"Some of our managers believe it is not the question if our assembly will move to a country where wages are low, rather the question is when it will move."*

The importance of logistic processes has also changed because of the reduction in storage space at the Small Car Co plant. At the moment Small Car Co has a warehouse of 5,000 square metres, which is one third of what it was ten years ago. Moreover, this warehouse is only used for the most basic high volume parts that do not come in many variants. Components that are car-specific are not stored in the warehouse because these are delivered Just-In-Time and directly to the production line in the right sequence. This development drives logistics efficiency improvements. For example, the instrument panel supplier will be informed three hours in advance about the exact specifications of the instrument panels it needs to deliver to Small Car Co. However, this is only possible if the supplier is situated very near the Small Car Co plant (in the case of the instrument panels the supplier is even situated inside the Small Car Co plant). For suppliers that have their factories in other countries (e.g. countries where wages are low) it is not possible for Small Car Co to order supplies several hours before they are needed. To cope with this problem Small Car Co communicates the planned sequence of cars on its production line to suppliers. This planning determines the order in which supplies should be delivered to the production line and suppliers in remote countries can determine when certain supplies are needed. By doing so, these suppliers are still able to deliver their supplies in sequence with the cars on Small Car Co's production line.

If all suppliers stick to the production planning, all components arrive at Small Car Co's plant at the right moment (i.e. Just-In-Time, or JIT) and in the right order (i.e. Just-In-Sequence, or JIS). Since Small Car Co has no warehouse for JIT and JIS supplies, these supplies are not taken out of the trucks before they are needed in the production process. Next to the Small Car Co plant is a trailer yard, which contains at any moment about 200 truck trailers with supplies. The logistics manager explained that:

> *"The trailer yard is basically a warehouse on wheels, which is managed by a push system (the supply from the suppliers according to the production planning) and a pull system (the need for supplies at our production line, which is translated into a Kanban system). This approach requires that everything is managed effectively otherwise the trailer yard would be in chaos."*

Therefore, Small Car Co demands from its suppliers that they deliver their supplies in the right order and in the right numbers. The packaging of the supplies is also an important issue because many different packaging systems would make the processes more difficult at Small Car Co. Apart from that the issue of recycling the large amount of packaging materials plays an important role. Therefore, Small Car Co demands from its suppliers that their packaging materials comply with the international system that is used by Small Car Co's owner. Another requirement to manage this whole system of JIT and JIS supplies and the trailers in the trailer yard is having a clear overview of what is happening at the suppliers and during transportation. Electronic Data Interchange (EDI) plays an important role in providing that overview. With EDI, Small Car Co knows exactly what supplies are under way to its plant. All these developments have meant a tremendous change from the past for Small Car Co. The current large variety of components that is needed by Small Car Co to produce cars that closely match consumer demands, means that storage of supplies is not possible anymore. Ten years ago, large warehouses allowed for inefficiencies, both at Small Car Co and at its suppliers. Today, if a component is defective, there will be no replacement available from the warehouse, and if Small Car Co does not stick to its planning it will need different supplies than the ones that arrive in its trailer yard. So, apart from the increased demands on suppliers, JIT and JIS also mean that Small Car Co's internal organisation should be such that it is possible to plan more than a week in advance.

Contract manufacturers like Small Car Co have become more attractive for car manufacturers/brand owners in recent years because of the low financial returns that many brand owners have realised on their assembly activities. The logistics manager explained that:

> *"From a shareholder value perspective one can argue that brand owners should not do activities that add little or no value, like manufacturing. However, outsourcing means that relations need to be managed."*

Especially when suppliers are located in distant countries it is very important to manage the relations and the processes. The logistics manager went on to claim that:

> *"Consequently, the core business of brand owners is slowly changing from assembling cars to controlling processes and logistics between suppliers and the actual manufacturer."*

Outsourcing and involving suppliers more closely in the production process is a matter of risk management for Small Car Co. All major parties (i.e. manufacturer and suppliers) involved in car production share the risks. Consequently, some of the suppliers may go bankrupt if they do not manage their business well enough. Therefore, it is especially important for the suppliers to manage the sub-suppliers very well. The supply chain manager pointed out that:

> *"All first tier suppliers know that we will charge them for the costs of stopping the production line if they are to blame for the line stoppage. However, not all second and third tier suppliers seem to be aware of this risk and therefore may take quality and responsiveness not as serious as they should. However, we will always send the supplier a bill if something goes wrong and it proves to be a result of their actions."*

This is a very transparent system because suppliers know how much it will cost if they fail to deliver as agreed in the contracts. Still, it happens regularly that Small

Car Co sends a bill to a supplier, which keeps the suppliers aware that they have to deliver top quality every time. Ten years ago, Small Car Co did not have this policy of billing suppliers for line stoppages because large warehouses provided a buffer when things went wrong. There was ample time to solve the problem before the stocks in the warehouses ran out.

All Small Car Co managers agreed that outsourcing requires very good preparation in order for it to be successful. The supply chain manager argued that:

> *"In the past many car manufacturers were not well prepared before they started outsourcing some parts of the production process. Consequently, problems already started before the start of production of a car model. Sometimes developments just went too fast and too far, which meant that car manufacturers had to do a step back again."*

Another reason why outsourcing sometimes failed at Small Car Co is because suppliers promise more than they can handle. Suppliers see possibilities to grow and develop by offering additional services in relation to logistic processes and managing the supply chain. These services would make it easier for Small Car Co to manage the supply chain but sometimes the supplier is just not (yet) capable enough to deliver what has been promised.

6.5 Continuous Improvement

In this section Small Car Co's efforts to achieve and maintain a culture of continuous improvement are discussed, and related developments are explained. The major factor underlying these developments has been the need to more closely involve different parties (e.g. management, employees and suppliers) in the process of continuous improvement. Relevant issues for Small Car Co are process improvement, improvement of employee knowledge and skills, and supplier improvement. These issues are dealt with in the remainder of this section.

6.5.1 Process Improvement

In an effort to make processes more efficient and more reliable, Small Car Co has increased automation and robotisation over the last couple of years. However, the extent of automation that is economically feasible is limited, and as a result the degree of automation of Small Car Co's production process is varied. The press shop is nearly completely automated and has very few opportunities to automate further, since it currently employs only 150 employees in three shifts. The body shop is about 70% automated. The paint shop is somewhat less automated because sanding of the cars and inspections are done manually. Spray painting inside the car is also still done manually but it will be automated soon. In final assembly the rate of automation is still lower. The production manager explained that:

> *"In final assembly only 20% of the tasks are automated and we do not see many opportunities to increase this percentage in a cost-effective way. There are limits to automation."*

However, developments like modular sourcing allow Small Car Co to improve efficiency in the final assembly without increasing automation. Modular sourcing is used by Small Car Co to reduce the number of individual parts and therefore the time needed to assemble a car.

Benchmarking is also used by Small Car Co as a way to improve its processes. For Small Car Co employees it is quite easy to look around in other car plants because it has links with several global car manufacturers. These car manufacturers are willing to allow Small Car Co employees to look around in their plants. However, it is not always of much use to look at processes in other plants. Especially during the start up phase of a new car model, production is not at a level that can be easily compared to other plants.

The changes in the environment that have taken place over the last decade and with which Small Car Co has to deal mean that new ways for improvement need to be developed. The quality manager argued that:

> *"More intelligent forms of quality management are needed than the basic measure-and-improve type of management to survive in the environment in which car manufacturers operate."*

Small Car Co's management believes that improvements nowadays need to be initiated at a very early stage, and that the organisation should go through improvement cycles faster than in the past.

Small Car Co learned from the Japanese that it should think already about improvements before the start-up of the production of a new car model. A frame in the shape of the car, to which all parts will be fitted, is used before the actual production starts. After this frame has come of the production line, it is analysed to see what has gone wrong and what could be improved. When that is clear, all improvements have to be made before the start of the pilot production. By doing so, the pilot production contains few errors and other quality problems. Therefore, only a few pilot series are necessary to remove most of the quality problems. The production manager explained:

> *"This was a lesson from Japan for us. While in Europe 1,000 problems in the first production run was quite normal, the Japanese had hardly any problems in the first production run because they already eliminated them during the pilot runs."*

This example underscores the benefits that can be obtained from starting improvement processes at an early stage.

Another important development at Small Car Co has been the increased speed with which improvements are realised. Some years ago, Small Car Co stopped prioritising production problems because all problems had to be solved anyway. At first this seemed to be impossible but in the end Small Car Co managed to do it, as explained by the quality manager:

> *"This is in sharp contrast with the more distant past. About fifteen years ago a list of problems was only drawn up after months of production. This list would subsequently be addressed in a structured way. Now we monitor processes constantly."*

During the start up phase of Model One and Model Two, Small Car Co sometimes discovered and solved more than 130 problems per day. This was achieved by a combination of Kaizen and high-speed problem solving.

If it appears that defects are not caused by individual employees but are structural in nature, immediate action should be taken. Small Car Co is keen on solving these problems quickly because they can result in many defective cars rolling out of the plant. In the past these problems could last for a relatively long time but nowadays Small Car Co does not accept that anymore. Therefore, Small Car Co's management now holds a meeting every morning at 8.30hrs in which the defects of the previous day are discussed. It is not acceptable that only the defect itself is described because it should be solved already. So, what Small Car Co's management wants to hear is a description of what went wrong and how it has been solved. This description should be given by the person who is responsible for the problem. Small Car Co's top management is very strict on this. The production manager commented:

> *"Even if the problem has been caused by a supplier, our top management still expects the supplier to send its responsible person to the meeting, to explain how the problem has been solved. The next morning top management will check if the problem really has been solved."*

Furthermore, an analysis is done on the problem that addresses two questions:

1. Why has this problem not been identified before?
2. Why did things go wrong? (i.e. Can the process be made more robust?)

The benefit of such an approach is that it clearly signals the importance of top quality products to everyone at Small Car Co and its suppliers. The downside is the amount of time it consumes every day and the difficulty trying to address each and every problem that has occurred during the previous day. To cope with this, Small Car Co prioritises quality problems by three major criteria:

1. Is it a safety issue? (i.e. does the defect influence the safety of the car?)
2. If it is not a safety issue, are consumers likely to notice the defect?
3. Did the problem occur with a single car or is it structural?

On the basis of these criteria, quality problems can be ranked. The most important ones are discussed during the daily meetings with top management, while the less important ones are left for the operational managers to solve. However, if this does not lead to satisfactory results on the very short term, the responsible person will still have to explain to Small Car Co's top management why he cannot fix the problem.

6.5.2 Improvement of Employee Knowledge and Skills

The demands with which Small Car Co has to comply are clear and understandable for everybody in the organisation. The main performance indicators for Small Car Co are delivery performance, costs and quality. Small Car Co is treated as an independent profit unit by its owner, so to survive on the long run quality and delivery performance should be high, while costs should be low.

A way to lower costs is by reducing the number of tasks that need to be done to assemble a complete car because this will lead to a reduction of the time that employees spend on a car. Automation and the use of robots are important factors in reducing the time spent per car. However, the fieldwork indicated that labour is not a very significant cost component for Small Car Co. The quality manager explained that:

> *"Labour costs are not even a major issue for us because they represent only 8% of the costs of a car. The amortisation of investments in equipment is the major cost component of a car."*

However, at the same time the employees are very important to Small Car Co for reaching quality and delivery performance targets. The quality manager went on to argue that:

> *"Employees have to take ownership of what they do. They should see and notice what is critical and what can be done to improve. The employees really make a difference in quality, both for assembly and for feedback to engineering."*

So, it is clear that the attitude of employees is very important for reaching Small Car Co's targets.

All Small Car Co managers were agreed that in the end it is the employee who determines the quality of the final product. So, the challenges for Small Car Co with respect to quality are strongly related to its employees. For example, a decision to move from two to three production shifts can result in lower quality levels. Small Car Co cannot just add a third shift that consists solely of inexperienced employees. Therefore, the existing two shifts are broken up and the third shift is composed of a third of the employees of the first shift, a third of the second shift, and a third new employees. Consequently, the other two shifts consist of two thirds existing employees and one third new employees. For the existing employees it can be demoralising to be split up and to have to work with new employees who make mistakes because of their inexperience.

The importance of Small Car Co's employees can also be seen from their role in measuring the quality of the cars. Over the years, the shop floor employees have become much more important for early detection of quality problems. Small Car Co measures quality at four different levels:

1. At the level of an individual employee. The employees measure the quality of their own work and if necessary they should take actions.

2. At the level of a production cell (i.e. team of employees). One employee in a production cell has specific quality tasks, and checks the quality of the output of the production cell.

3. At the level of the quality department (i.e. final product tests). The final product is tested by means of snap checks. In addition, employees of the quality department act as watchmen in the whole production process to spot quality problems. If problems are found by the quality department the car is disassembled to find the cause of the problem.

4. At the level of the quality department (i.e. customer audits). Every day, eight to ten cars are checked in the customer audit department. Problems that are found should be solved within twenty hours, to prevent the problems from reaching the customers.

To realise improvements for the longer term it is necessary that the processes can be traced back to the individual employee. Ten years ago Small Car Co was only able to indicate at what stage of the production something went wrong. However, if a defect is found and there is no way of pinpointing the employee who caused the defect, then there is no opportunity for improvement. Therefore, today Small

Car Co can exactly tell the moment something went wrong and, more importantly, the employee who made the mistake. The quality manager pointed out that:

> *"The employees should feel ownership of the problems that have been found. If an employee feels that he is responsible for the part that caused the problem, then he will probably also try to understand what exactly went wrong, to be able to solve the problem for the future."*

If it is known who caused a defect then this person can receive training to improve himself.

Small Car Co's paint shop is an example of the usefulness of traceability. In the past the paint shop used to cause many defects and Small Car Co had, at that time, no means to trace back who was responsible for these defects. The standard response from the employees in the paint shop was that the defects were caused by the equipment. However, Small Car Co found out that the same equipment in other car plants did not result in defects. So, the conclusion was reached that the employees in the paint shop were causing the defects. Thereafter, Small Car Co started to develop measurement systems and feedback loops for the paint shop. This means that objective measurements are done and defects are reported by management to individual employees. By doing so, Small Car Co managed to reduce the number of defects, so this has been a successful approach. However, for the feedback to have positive results, management has to make sure that the feedback is fair and not meant to blame the employees but instead allow the employees to learn from their mistakes.

Consequently, measuring objectively and giving feedback about defects to individual employees also required changes from Small Car Co's managers. Therefore, they are now trained in a 1.5 year program, which focuses on:

- Defining responsibilities and dealing with them.
- Performance measurement.
- Using facts instead of ideas and feelings.
- Problem analysis: knowing how to deal with problems and which experts are available at Small Car Co to help solve them.

The shift over the last couple of years towards involving employees in the management of quality at Small Car Co has contributed to preventing defects from showing up during inspection by quality inspectors. Still, some shop floor employees do not always decide to notify a supervisor when they find a defect in their work. Employees should both finish their task and check if they did it properly, within the standard cycle time. So, if a defect is found there is not much opportunity for the employee to correct it. The quality manager explained:

> *"In that case he can choose to let the car move on and hope that the defect will not cause problems further down the production line, or he can call a repair man to fix the problem."*

Repair men are experienced employees who fix defects next to the production line. This is of course not in line with the goal of high efficiency but the only other option for Small Car Co would be to allow employees to stop the production line. However, this is only possible if quality is high because otherwise it is too costly. Stopping the production line will quickly lead to problems due to the very small buffers. If the line is stopped, it will take only ten minutes to empty all buffers and thereafter all employees at the production line will have no work to do. The managers indicated that Small Car Co is not yet at a quality level for Model One and Model Two that it can allow employees to stop the line.

If individual employees do not notice their mistakes or knowingly let them go further down the supply chain they may be found by the employee who is responsible for quality checks of his production cell or by an employee of the quality department. Inspectors from the quality department use a check list that is partly based on the issues that show up during final inspection and customer audits. The quality inspector cannot check all issues on all cars, so he does snap checks on the cars that are on the production line. If the quality inspector finds a defect, he has little time to repair it because he is restricted by the cycle time. Therefore, he has to follow the same procedure as a shop floor employee if he cannot fix the defect within the cycle time, which means that he has to call a repair man who will fix the defect next to the production line.

Although the changes in the role of shop floor employees over the last decade have been significant, the aims are still the same: low costs and high delivery performance and quality. The human resources manager argued that:

> *"In effect it is all about providing the customer at the right moment with the right product for minimal costs. Even in today's more complex environment with complicated relationships which make it more difficult to manage the whole plant, these are still the three demands with which we have to comply."*

Nowadays, the customer side of the process has become more complex than ever before because of the fluctuating demand for individualised products, while on the other hand the supply side has become more complex because of the constant pressure on suppliers to take up a larger part of the assembly process (e.g. modular sourcing and managing their supply chain) and to reduce costs (including costs of logistics). This development has two consequences that affect the employees at Small Car Co:

1. The plant has to become more flexible, which means that the employees should be organised in a different way.

2. The employees themselves should become more flexible (e.g. by working under flexible contracts and by receiving training).

Small Car Co tries to become more flexible by adapting the extent to which it makes use of the available operating time to external factors. There are two major external factors that necessitate Small Car Co to be flexible:

1. Customer orders are not constant all year round.

2. The stage of the life cycle in which the car models are influences demand (i.e. new cars attract many customer orders and dealerships are trying to fill up their showrooms, so demand is high)

To be able to adapt to these two external factors, Small Car Co has in recent years come to an agreement with its trade unions about the way it employs people. This is the only way in which Small Car Co can adapt to fluctuations in demand because in principle the speed of the production line will not fluctuate. The human resources manager explained:

> *"We agreed with our trade unions on a flex covenant, which is a memorandum of understanding about flexible use of labour. The flex covenant allows us to make employees work longer or shorter, depending on customer demand for cars."*

In the flex covenant, arrangements have been made for the following:

- Small Car Co is allowed to vary the length of a shift within certain limits.

- Small Car Co is allowed to send its employees home for a number of days per year at no extra costs. The employees then have to take a day off from their own stock of free days. This option is used mostly around Christmas because demand for cars is then very low. Therefore, the factory is usually closed for one or two weeks around Christmas.

- Small Car Co is allowed to ask employees to work four Saturdays per year, without paying a high surcharge to them (however, Small Car Co still has to pay some surcharge).

The employees of Small Car Co can understand the need for such a flex covenant but that does not mean that they are always happy with it. However, the fact that the employees decided to support the covenant says something about the extent to which the environment of Small Car Co has changed because the view from the managers interviewed is that a decade or so ago the employees would be unlikely to agree with such measures.

Also in terms of teamwork and training, a lot has changed for the employees. Small Car Co has organised its employees in teams already for many years. However, the role of the teams in the organisation has become more important over time. In the past the teams were mainly responsible for the direct assembly work, while they now have to operate as independent units that organise and arrange tasks among themselves (e.g. arranging a proper occupation of all tasks within the team, quality control, arranging scrap materials etc.). There is a coordinator within each team who is responsible for making sure that all these tasks are done by the team. A new task within the teams is being a tutor for new employees, which means that existing team members have to support and guide new team members.

Within the Small Car Co organisation there have been discussions about linking salaries to quality performance of employees (e.g. first-time correct percentage). However, fears have been raised that this would cause the employees to work as an individual instead of as part of a team. It is important for Small Car Co that employees have joy in working together with the colleagues in their team. An atmosphere of cooperation leads to open discussions about quality problems. The human resources manager explained that:

> *"In the past employees were punished for making mistakes which caused the employees to conceal their mistakes. Nowadays, we want to avoid such situations."*

Therefore, Small Car Co wants to make teams responsible for their total performance, instead of focusing too much on the individual performance of employees.

Training of the employees is also arranged within their team. This does not only mean that a team has to suggest to the management which employees need a certain type of training, but it also means that the team is responsible for making sure that someone else can replace an employee who is receiving training. The human resources manager commented that:

> *"We have a no-nonsense policy regarding training, which means that a training programme should be necessary for the job that an employee has to do. However, we try to make our employees capable of doing multiple tasks."*

Small Car Co has learnt over the years that it can be counterproductive to give employees too much general training. Nowadays, Small Car Co is also paying more attention to existing skills of people that it considers to hire as an employee.

Regarding training, Small Car Co nowadays employs an ILU training matrix. ILU is not an abbreviation but a graphical representation of a process that adds lines together until a box emerges (i.e. an employee starts with one line, which is the I, when he receives a second line the I turns into an L etc.). According to the human resources manager, the idea behind this ILU approach is that:

> *"All employees should be capable of performing at least three different tasks. When they manage to perform the first task, they receive the I, after the second task they receive the L, and after the third task they receive the U. Once they are capable of doing at least three tasks, they can make the box complete by trying to obtain a trainer's certificate, which makes them suitable for training new employees."*

The ILU training matrix is the responsibility of the teams of employees. So, the teams have to make sure that their members are sufficiently skilled in order to enable the team to do all necessary tasks and to have these tasks done by qualified employees. This emphasis on training is something that has been developed at Small Car Co only in the last couple of years. A decade ago the need for training was much less because employees would confine themselves to a single task (or at most a very limited number of tasks). Moreover, most tasks were more straightforward than they are today because of the limited number of variants that employees needed to cope with.

6.5.3 Supplier Improvement

Since Small Car Co's performance is assessed by its owner on the basis of costs, quality and delivery performance, Small Car Co uses the same performance indicators towards its suppliers. In absolute terms the norms on these criteria have become much stricter over the last decade. For example, in relation to quality, the defects norm in defect parts per million produced (PPM) has halved in the last couple of years. So, suppliers have to comply with increasingly tough demands and therefore they constantly have to improve their performance. The supply chain manager explained that:

> *"Suppliers need to have a mindset of continuous improvement on all important criteria to be able to succeed. In the automotive industry it is generally accepted that the bar is raised all the time."*

An important improvement for Small Car Co has been the modular sourcing trend. Combining individual parts in modules reduces the number of supplies that are needed to build a car and therefore reduces the chance of defects caused by employees of Small Car Co. However, it means that suppliers have become responsible for a larger part of the assembly process and, consequently, their chance of making mistakes has only increased. This reinforces the need for suppliers to continuously improve their performance. An example of how the modular sourcing trend has shifted assembly work from Small Car Co to its suppliers is the dashboard of the Model One and Model Two. In the past a dashboard consisted of 15 parts and Small Car Co needed to add all other parts as individual supplies. The dashboard of Model One and Model Two consists of 75 parts and can be installed as one complete module without the need for any additional individual supplies (like steering wheel, radio, air conditioner and pedals). The logistics manager explained:

> *"Modular sourcing makes production easier for us but more complex for the supplier, which increases our risks."*

The difficulty for the supplier is to build the right cockpit at the right time. The variety of cockpits is so large that the supplier cannot build cockpits in advance and put them into stock. Small Car Co informs the supplier about the cockpit that is needed three hours before it should be installed in the car. So, the supplier has only three hours to build the complete cockpit and send it to Small Car Co's production line.

Given the high risks of selecting the wrong supplier in an environment of modular sourcing, the owner of Small Car Co employs purchasing specialists who are responsible for supplier selection. These purchasing specialists are organised in global sourcing committees for specific car parts. The owner of Small Car Co does not allow its plants to choose suppliers single-handedly because it feels that global sourcing committees will be of benefit to all plants. The owner of Small Car Co has more than 100 plants worldwide and by sharing experiences with suppliers among each other, mistakes can be prevented. A global sourcing committee keeps track of all suppliers in the industry for one or several components, and ranks their performance on the basis of previous experiences with these suppliers. During the development of a new car model, a global sourcing committee will analyse the requirements of a car part that is needed and thereafter assess which suppliers can offer the right part with respect to specifications, quality and costs. On the basis of this whole process, the global sourcing committee will recommend a supplier to the approval committee and the commodity director of Small Car Co's owner. If these agree with the recommended supplier, the recommendation is sent to the purchasing manager at the plant. So, the decision making really takes place at headquarters level for all plants that belong to the car manufacturer. Small Car Co is only one of these and has no power to select a supplier, although an individual plant's purchasing manager may still request for another supplier but this request has to be reviewed by the global sourcing committee.

The global sourcing committees do not only look for the best supplier for a car part but also at strategic issues for the long term. This means that sometimes a supplier may be recommended that is not the best performing supplier but still it is recommended because the best performing supplier is growing too large. If a supplier becomes so large that it has a monopoly on certain car parts, car manufacturers are dependent on that supplier. The supply chain manager gave an example:

> *"The German supplier Robert Bosch basically has a monopoly on fuel injection systems. Suppliers that have a monopoly are not very willing to reduce the prices of their products because they know that car manufacturers have to buy from them anyway."*

The owner of Small Car Co wants to prevent a situation similar to Bosch developing in the future and therefore it awards contracts to suppliers who are not the best in class if this will stimulate competition between the suppliers. The seats in the Model One and Model Two are an example of this. The seats of the previous car that was manufactured at Small Car Co were supplied by supplier 2, which did a very good job. Still, the owner of Small Car Co chose to award the contract for the seats of Model One and Model Two to supplier 3 because supplier 2 had become too powerful in the seat market (because of acquisitions etcetera). Supplier 3 had to set up a new plant and it had to retrain employees who were previously manufacturing car exhausts. So, Small Car Co could expect problems with the seats, which is also what happened. However, by allowing supplier 3 to build up expertise in the area of seat manufacturing, the owner of Small Car Co increased the likelihood that there will be competition in the seat market in the future. This way of awarding contracts is normal for the owner of Small Car Co since it happens quite often.

Small Car Co has been trying to develop more cooperative relationships with its suppliers over the last couple of years. However, being a part of a larger organisation, Small Car Co has to deal with perceptions that suppliers have about its owner. Not all parts of the whole organisation deal with suppliers in a cooperative way. The supply chain manager explained that:

> *"Even though our owner explicitly aims at establishing cooperative relationships with our suppliers, there may still be some parts of the larger organisation that maltreat the suppliers."*

In general, Small Car Co's management sees a trend from adversarial relationships towards cooperative relationships in the automotive industry. However, it will always remain difficult to implement a group strategy in a large organisation with many different plants in many different countries. Each plant will interpret the strategy in its own way and each individual will act on it in a different way. So, the different plants are also likely to translate their demands in a different way towards the suppliers. The supply chain manager believes that:

> *"As long as transparency is maintained towards suppliers, things will turn out okay. Because manufacturers can demand a lot from suppliers but in the end they have to be able to offer something back otherwise the relationship will not last."*

He went on to argue that with respect to supporting and cooperating with suppliers, Toyota is the great example. He explained:

> *"Toyota is very keen on helping its suppliers to improve their products and processes. If there are problems at one of Toyota's suppliers, Toyota will send some of its people there to help solve the problems. Even if it takes a long time to solve all the problems, Toyota will stay committed to the supplier."*

At the same time all Small Car Co managers acknowledged that their way of cooperating with suppliers was not at this level yet.

6.6 The Supplier's Perspective

The interviews with the management of Small Car Co have shown that the importance and responsibilities of suppliers have increased. Modular sourcing of car components has resulted in a need for more sophisticated suppliers and also in a longer supply chain. For the quality of the final product it is essential that Small Car Co manages this supply chain to maximum effect. Apart from the view of Small Car Co's managers on the way they manage the supply chain, it is important to understand the perceptions of their first tier suppliers, which are the other parties in these dyadic relationships. Therefore, this section deals with the views of three suppliers about the changes that have taken place over the last ten years in their relationship with Small Car Co. These suppliers have been selected by the quality manager of Small Car Co on the basis of their importance in terms of the components they supply, and on the impact these components have on the final product.

6.6.1 Supplier 1

Supplier 1 manufactures bumpers and other plastic body parts for Small Car Co. The complete front-end and rear-end modules of Model One and Model Two are manufactured by this supplier. It is a first tier supplier, which has its plant situated inside the Small Car Co plant. The modules are delivered to Small Car Co according to the Just-In-Time principle and also in the right sequence. The supplier 1 plant is dedicated to Small Car Co production, generating a turnover of about 50 million Euros.

Supplier 1 is an important supplier to Small Car Co because interruptions in its production process would have a large impact on the production process of Small Car Co, even though the modules it assembles are used at a late stage in the production process of Small Car Co. A second reason why supplier 1 is important to Small Car Co is the fact that it is Small Car Co's only supplier of the front-end and rear-end modules. In addition, these modules are very specific to the car models that Small Car Co assembles, so Small Car Co cannot easily switch to an alternative supplier in case of problems.

The front-end and rear-end modules come in many variants. They are not only available in different colours but also in many different configurations of lamps, reflectors, grilles, strips etcetera. Many of these variants are only slightly different, which means that employees should be alert when picking the different parts for each module. The variants also differ in the amount of time needed to assemble them. However, supplier 1 has to operate its production line at the same takt time (i.e. speed) as Small Car Co, in order for the two production lines to connect smoothly. This means that the time per module is always the same for supplier 1, no matter how complicated a module is. Therefore, supplier 1 should have its processes under control and it should be able to assemble even the most complicated module within the given takt time.

When a quality problem with a module shows up at the end of supplier 1's production line, there will not be enough time to assemble a new module and deliver it in time to Small Car Co. Moreover, assembling the same module twice is not possible in the normal production line of supplier 1, which means that the module will have to be assembled beside the normal production line and then brought by an employee to Small Car Co. This employee of supplier 1 will have to find the car that is missing the module and then install it on that car. Needless to say that such incidents disturb the production process, both at supplier 1 and at Small Car Co. Therefore, it is of critical importance for supplier 1 to maintain very high quality levels. If supplier 1 has a structural problem with its modules and it causes a stoppage of Small Car Co's production line, supplier 1 will have to pay the bill. According to supplier 1's quality manager this is an issue that is on top of everybody's mind:

> *"Every supplier knows that stopping Small Car Co's production line means that you have to pay a fine. So, everybody wants to avoid that at all costs."*

Another reason why quality management is very important to supplier 1 is the price pressure in the car market, which car manufacturers try to pass to their suppliers. The margins on supplies are so small that efficiency and quality must be excellent in order to survive. Supplier 1's quality manager indicated that:

> *"Many of the quality tools and techniques that are used nowadays were already available in the past (e.g. fishbone diagrams, failure modes and effects analysis). However, nowadays they are used much more seriously than in the past and also with clear success. In the past people would also talk about the quality tools and techniques as the latest thing to do, while now they are to some extent integrated in the normal management approach (e.g. design of experiments)."*

This indicates that quality is now taken more seriously than in the past. Another change that has happened over the last 15 years is the increased loyalty between Small Car Co and its suppliers. Suppliers need to have specific capacities in order to be able to build modules for cars. This means that Small Car Co has become more dependent on these module suppliers' expertise, which has led to closer cooperation between Small Car Co and its suppliers. Supplier 1's quality manager feels that at the beginning of the 1990s the owner of Small Car Co was loyal to its suppliers but later on this loyalty has started to decrease. The owner of Small Car Co started to focus more and more on selecting the cheapest supplier it could find, even if this meant that it had to change suppliers frequently. However, the quality manager notices that from the middle of the 1990s the owner of Small Car Co seems to have become once again interested in developing partnerships with suppliers.

6.6.2 Supplier 2

Supplier 2 manufactures the instrument panels for Small Car Co's Model One and Model Two. Just like supplier 1, supplier 2 is a first tier supplier, which has its plant situated on the supplier park around the Small Car Co plant. In fact the production line of supplier 2 is situated inside the Small Car Co plant. The modules are delivered to Small Car Co according to the Just-In-Time principle and also in the right sequence. The supplier 2 plant is dedicated to Small Car Co production, generating a turnover of more than 100 million Euros.

Supplier 2 is an important supplier to Small Car Co because it is Small Car Co's only supplier of instrument panels. Moreover, the production line of supplier 2 is physically connected to the production line of Small Car Co. At the point where both production lines meet, a robot installs the completed instrument panel in the right car. The instrument panels that supplier 2 manufactures are unique because they include more components than usual in the automotive industry. Items such as pedals, steering wheel and air conditioner are already part of the instrument panel module before it is installed in the car, which is exceptional. These specific capabilities of supplier 2 make it difficult for Small Car Co to switch, in the short term, to a competing supplier.

Given the large number of components that are part of the instrument panel, the number of variants is enormous. The quality manager at supplier 2 could not give an exact number but he provided assurance that an extremely large number of configurations are possible. The variations are in colours, materials, radio, air conditioner, automatic gearbox, cup holders, sports packages, wood trim etc. These different instrument panels are all mixed up on the production line because supplier 2 delivers them in sequence to Small Car Co.

This current situation is very different from the situation that existed several years ago. During those years, supplier 2 was manufacturing the seats for the cars that Small Car Co manufactured at the time. These seats came in very few variants and therefore production was straightforward. Also in terms of quality management things have changed drastically over the last decade. There are no warehouses anymore with finished products, so there is no time anymore to correct mistakes. Therefore, it is extremely important to prevent quality problems from occurring. However, when they do occur, suppliers should have short communication lines with key people at Small Car Co to quickly solve problems when they occur. The quality manager of supplier 2 explained that:

> *"The quality of a supplier is always strongly related to the person at Small Car Co who is made responsible for this supplier. Small Car Co employs people who are each responsible for one supplier. These contact persons should identify themselves with 'their' supplier and regard the performance of their supplier as their own performance. The extent to which contact persons do this makes a big difference for the performance of the suppliers."*

A good contact person knows the hierarchy at Small Car Co and can help solve problems quickly. Therefore, suppliers are keen to have a good contact person at Small Car Co. The quality manager of supplier 2 has been working at Small Car Co before moving to supplier 2 and therefore he knows the people at Small Car Co, which makes it easier to communicate.

Since it is nowadays very important for supplier 2 to focus on preventing quality problems, appropriate checks have been integrated into the production line. As the instrument panel moves from work station A to work station B, an employee at work station B will first check if the person at work station A did a good job. By doing so, mistakes and defects are found at an early stage when it is still relatively simple (and quick) to correct them. This approach is in line with the 'successive inspection system', as developed by Shingo (1986).

In addition to preventing problems from occurring during its own assembly process, supplier 2 has started to pay more attention to the second tier of suppliers. Because of the large number of components in the instrument panels, supplier 2 has to deal with many second tier suppliers. Supplier 2 has made clear to second tier suppliers that it is their responsibility to prevent and solve problems with the supplies they dispatch, as supplier 2 does not check any incoming supplies. Therefore, problems with supplies will only be noticed during the assembly process of supplier 2.

To reinforce its demand for defect free supplies, supplier 2 uses similar contracts towards second tier suppliers as Small Car Co uses towards first tier suppliers. The quality manager commented:

> *"The strict contracts that are used and enforced in the automotive supply chain ensure that every organisation is aiming for zero defects. Everybody knows the consequences of manufacturing defect products. This stimulates all parts of the supply chain to continuously improve products and processes."*

However, problems can always occur, and when they do, the responsible organisation has to make sure that they are solved quickly. In most cases, second tier suppliers have to solve their problems on their own, however, sometimes supplier 2 sends an employee to suppliers to assist. It is important that the different organisations in the supply chain exchange information, especially in relation to defects and complaints, because of the scale on which things can go wrong. The quality manager provided the following example:

> *"In the past we would have a complaint about one stitching that was loose on a seat, while nowadays we can have 1,200 instrument panels that have been spray painted in the wrong colour. This makes problems very complex for all parties involved."*

So, cooperation within the supply chain and fast communication have become of great importance in recent years.

6.6.3 Supplier 3

Supplier 3 assembles the seats for Model One and Model Two at the supplier park around Small Car Co. Like supplier 1 and 2, supplier 3 delivers its products in the right sequence and Just-In-Time (JIT) to Small Car Co. Supplier 3 manufactures and delivers the seats in sets of three (i.e. two front seats and a rear seat) to Small Car Co. Supplier 3 is the only supplier of seats to Small Car Co, and it would not be easy for Small Car Co to switch to another supplier in case of problems.

The variety of seats is high, coming in about thirty base variants: normal or sports type, manual or electrical adjustments, height adjustable or not, number of airbags etcetera. On top of this there are a variety of upholstery options (e.g. colour, fabric and an optional table integrated in the backrest). Consequently, it is not an option to assemble the seats to plan and put them in stock. Supplier 3 can only build to order from Small Car Co, which means producing according to the JIT principle because Small Car Co will only order a set of seats a couple of hours before they are needed in Small Car Co's production process. This way of operating also has consequences for the management and improvement of quality. The quality manager of supplier 3 feels that:

> *"The world was simpler in the past than it is today because in the past there were no JIT processes. JIT greatly influences an organisation's capabilities to solve quality problems. Without JIT it is easy to solve problems. In a JIT process, like the one we have to deal with, every 80 seconds a set of car seats has to be sent to Small Car Co, no matter what happens."*

If there was no JIT process, supplier 3 could just stop the production line in case of problems and look for a solution.

Improving the quality of its products for supplier 3 also means that the quality of its supplies should be improved. If the incoming supplies contain many defects, then this is likely to influence the products that supplier 3 sends to Small Car Co. So, tier two suppliers need to be made aware of the need to improve. The experience of the quality manager is that:

> *"Tier two suppliers will already improve their quality just by inviting them over to our office and explaining what is expected of them."*

However, if this does not bring the expected results, supplier 3 will engage in regular discussions with tier two suppliers that cause problems.

An issue for the quality manager of supplier 3 is the extent to which products and processes need to be improved. He feels that Small Car Co is more critical than the consumer who will eventually drive the car, which he thinks is not a good thing because:

> *"This causes a lot of extra pressure on the suppliers but still it cannot prevent consumers from getting dissatisfied, because many consumer complaints are related to the durability of the cars."*

An issue with the seats is for example the durability of the upholstery. The fabric is not strong enough to withstand the wear and tear that is caused by the movements of the human body. This is of course a serious issue but supplier 3 could predict that this would happen because during the contract negotiations between supplier 3 and the owner of Small Car Co, the cheapest fabrics were selected to save costs.

6.7 Discussion of Findings

The case description in this chapter has shown that both Small Car Co and its suppliers are influenced by the two trends of shortening product life cycles and increasing product variety. Product variety for the current two car models is higher than for any previous car model that Small Car Co produced. Similarly, the expected life cycle of the current two car models is shorter than for any previous car model that Small Car Co produced.

The management and improvement of quality is clearly still very important to Small Car Co. The management claims that high quality performance is the only way to operate efficiently. Operating efficiently is in turn an absolute necessity to survive over the longer term, given the fact that Small Car Co receives 12% to 14% of the value of every car that leaves the plant.

The way in which Small Car Co manages quality contains elements of both prevention and cure (cure includes identification of fault, analysis of causation, rectification of fault, and then back, if structural, to prevention of reoccurrence). Small Car Co has over the last ten years devoted more efforts in preventing quality problems because it has realised that curing quality problems has become less effective. Ten years ago it was very well possible for both Small Car Co and its suppliers to solve defects once they occurred. However, the current high speed, low margins, absence of warehouses, and in sequence production of highly diverse cars have together made it impossible to only rely on curing quality problems when they show up. As production has largely been outsourced, and suppliers are moving further away from Small Car Co, there is no time anymore to solve problems once they occur. This is in line with the findings of the most recent American Society for Quality (ASQ) triennial survey of quality management experts, which aimed to identify the key forces that will shape the future of quality management (Phillips-Donaldson, 2006). This survey found that prevention and incorporating quality in the design process are considered to be the second most important factor to influence quality management (the first factor being globalisation). The surveyed quality experts indicate that quality management is about to change significantly:

> *"The next era will be quality of design. Our profession will transform into risk management."*
>
> *"Designing quality into our products at the development stage will be a competitive edge."*

However, prevention of quality glitches alone is not enough. Small Car Co understands that being able to cure quality problems is still important and therefore it has strict systems in place, like quality reviews, rapid problem solving, and charging suppliers for faults.

Apart from the distinction between prevention and cure, the importance of the employees has also become clear from the Small Car Co case study. As explained earlier, quality management is of key importance to Small Car Co, and all prevention and cure methods of Small Car Co depend on the employees using the methods properly. Therefore, data such as, 8% percent of the total costs of a vehicle are labour costs, in no way reflect the importance of people to the profits of Small Car Co. The more Small Car Co has invested in automation and robotics, the more it has started to rely on people working together to get them working in the right way. Likewise, the more Small Car Co has outsourced, the more it has started to rely on people working together to ensure quality is maintained. So, what matters is not the cost of labour in relation to total cost, but the size of risk that poorly working employees represent.

The design of the car models that Small Car Co produces has changed over the last decade with respect to the way in which differentiation between car models is achieved. Different car models used to be built from different components, although they would sometimes share the same platform. Currently, the two car models that Small Car Co produces are differentiated as much as possible for all parts that are visible to the consumer, while utilising standardised components for all parts that are invisible to the consumer. This trend is expected by the management to continue in the future.

Responsibility for quality has moved away from the quality department to every department in the organisation. Departments like purchasing, logistics, human resources, and production now all have many more responsibilities in terms of managing and improving quality than was previously the case.

A consequence of outsourcing large parts of the assembly process is that the main role of Small Car Co has gradually shifted over the last decade from manufacturing to managing relationships with suppliers. Today, suppliers are more important and they are situated further away from the plant than before, and even though the number of first tier suppliers has been reduced, the number of second and third tier suppliers has increased significantly. The case analysis has shown that manufacturing requires different quality competences than managing relationships.

The mentioned developments are summarised in table 6.3, where each row indicates one development from past, via present, to future.

Table 6.3: Developments over time at Small Car Co

Past	Present	Future
▪ Few product variants	▪ Many product variants	▪ Many product variants
▪ Average product life cycles	▪ Very short product life cycles	▪ Very short product life cycles
▪ Focus on curing quality problems	▪ Focus on preventing quality problems at first tier suppliers	▪ First tier suppliers become responsible for preventing problems at higher tier suppliers
▪ Production in-house	▪ Production to a large extent outsourced	▪ More outsourcing, while suppliers move to more distant countries
▪ Simple cars	▪ Complex cars	▪ Even more complex cars
▪ Automation is key to high quality products	▪ Employee is key to proper use of equipment and high quality products	▪ Employee is key to proper use of equipment and high quality products
▪ Shop floor employees build up task routines	▪ Product and task variety forestall routines	▪ Product and task variety forestall routines
▪ Different car models with different components	▪ Differentiate visible parts between car models, while standardising invisible parts	▪ Differentiate visible parts between car models, while standardising invisible parts
▪ Quality department is responsible for managing quality	▪ Quality is the responsibility of all departments	▪ Quality is the responsibility of all departments
▪ Managing manufacturing operations	▪ Managing suppliers	▪ Managing relationships between suppliers, manufacturer and customers

The case analysis has shown that the way in which Small Car Co manages and improves its quality has changed in a number of ways over the last decade, with the following being the major ones identified:

- The many product variants make processes more complex and unpredictable. Not only has the assembly process become more challenging but also the product development processes. To cope with the resulting demands on people and processes, Small Car Co keeps certain parts of processes constant at all times. No matter what car variant is produced or developed, there are clear boundaries as to what can be changed and what has to remain standard. Obeying these boundaries is an important means to prevent quality problems.

- Shop floor employees are held accountable for their own tasks to a much larger extent than ever before. Quality gates in the production process make clear to everyone involved who is responsible for the car at any moment during the production process. Despite the many tasks that have been automated over the years, the employees' commitment to their jobs is more important than before to the quality of the final product. This can also be seen from the fact that the percentage of employees on a temporary contract has actually been reduced because these employees are usually least committed to their jobs.

- Because of the increase in outsourcing, quality management is now much more focused on suppliers. The suppliers are motivated to deliver good components by, on the one hand, threatening them with high fines in case of defects and, on the other hand, by closely cooperating with them.

- The rate of problem solving has had to increase in speed. The current operating environment is such that, once something goes wrong in the production process, there is very little time to solve the problem.

- Management of second and third tier suppliers had traditionally been done by Small Car Co. Due to the enormous complexity of this task and the importance of the supply chain for the quality of the final product, Small Car Co has shifted this responsibility to first tier suppliers. However, in many cases it has turned out that first tier suppliers are incapable of managing their supply chain. Therefore, Small Car Co will in the future pay more attention to the supply chain management capabilities of suppliers when awarding them contracts.

The mentioned developments in the quality management systems are summarised in table 6.4, where each row indicates one development from past, via present, to future.

Table 6.4: Developments in quality management systems at Small Car Co

Past	Present	Future
▪ No need to emphasise manufacturing principles because of low variety	▪ Clear communication to corporate customers about limits to car assembly	▪ Clear communication to corporate customers about limits to car assembly
▪ Responsibility taken away from employees	▪ Employees are responsible for the quality of their own work	▪ Employees are responsible for the quality of their own work
▪ Responsibility for cars in production unclear	▪ Quality gates that indicate who is responsible	▪ Quality gates that indicate who is responsible
▪ Newly hired people on temporary contracts	▪ Temporary contracts not allowed to exceed 30% of workforce	▪ Temporary contracts not allowed to exceed 30% of workforce
▪ Defect supplies taken away from production line and replaced from stock	▪ Suppliers fined if they cause line stoppage because of defect supplies	▪ Suppliers fined if they cause line stoppage because of defect supplies
▪ Internal problem solving	▪ Cross-organisational teams, and familiar people at key supplier positions	▪ Cross-organisational teams, and familiar people at key supplier positions
▪ In-house design	▪ Supplier involvement in design process	▪ Supplier involvement in design process
▪ Process problems solved during pilot production of new car model	▪ Process problems solved before pilot production, by means of prototype assembly	▪ Process problems solved before pilot production, by means of prototype assembly
▪ Small Car Co manages whole supply chain	▪ First tier suppliers manage their supply chain	▪ Small Car Co selects suppliers that are capable of managing their supply chain

6.8 Summary

In this chapter the case company Small Car Co has been discussed. It has been explained that this company is relevant for the research because it has to cope with increasing product variety and shortening product life cycles.

The management and improvement of quality is more important than ever before at Small Car Co. For each of the three building blocks of quality management (i.e. customer focus, reduction of variation in organisational processes, and continuous improvement), Small Car Co has in place many tools, techniques and systems. Some of these have been used for a long time, while others have only been introduced during the last decade. The reasons for introducing these tools, techniques and systems can be diverse, however they all have to do with the need to adapt the quality approach to changing challenges and demands. One of these changes has been the increase in product variety and the shortening of product life cycles. From the case analysis in this chapter it has become clear that many developments are, either directly or indirectly, a consequence of product variety and product life cycle trends.

To understand how the changes and developments at Small Car Co compare to those at the other two case companies, a comparative analysis is undertaken in chapter 8.

7 Case Study 3: Premium Car Co

7.1 Introduction

This chapter describes case company 3, which has been named Premium Car Co. The general characteristics of Premium Car Co are presented in table 7.1. The Premium Car Co plant that has been the object of this case study is a single production location of the entire Premium Car Co organisation, which is in turn a subsidiary of a global car manufacturer. The entire Premium Car Co organisation assembles several car models that are sold globally under the Premium Car Co brand. The Premium Car Co production location that has been the object of this case study currently assembles only one lower premium car model. This production location is also the only plant in the world where this specific car model is produced. Premium Car Co started assembling this car model in 2001 and expected it to have a life cycle of eight years. So, at the time of this study the car model was halfway through its planned life cycle. Prior to 2001, the Premium Car Co plant had been assembling non-premium cars for the owner of Premium Car Co, but because of declining production volumes of that non-premium car and increasing volumes at Premium Car Co itself, the plant became a dedicated Premium Car Co production location. Therefore, the plant itself does not have a long history of assembling premium cars and comparisons with the past in this study would mean that only the recent past says something about developments at Premium Car Co, while comparisons with the more distant past would mean comparing premium car production with non-premium car production. However, the interviewed managers do have experience with the more distant past of Premium Car Co and could therefore trace back the developments at the Premium

Car Co plant to developments that started earlier in the long history of the whole Premium Car Co organisation.

The methodology of the research has been described in detail in chapter 4. Therefore, this chapter only describes the data that have been collected from the case company by means of interviews, document study, factory tours and feedback meetings. Table 7.2 provides an overview of all interviews and factory tours that have taken place at Premium Car Co and its suppliers. During the interviews, the managers of Premium Car Co and its suppliers have presented their views and opinions, however, whenever possible these views have been supported by relevant facts. Moreover, the data about Premium Car Co reported in this chapter are not just the quality manager's views, because all issues presented have been raised by at least two Premium Car Co managers. In addition, factory tours and document studies have been used to support the information from the interviews. These forms of cross examination (i.e. triangulation) of the case study are intended to improve the reliability of the results. Direct quotes are used throughout the text to support the statements made. If an interview has been conducted in another language than English, the presented quotes are a translation of the original quotes, agreed with a native English speaker who is also fluent in the language of the interview.

Following the introduction, the relevance of the case company in relation to the topic and aims of this research is explained. The data from the case company are then presented to explain what relevant developments have taken place at the case company over the last ten years. These data are structured along the three building blocks of quality management (i.e. customer focus, reduction of variation in organisational processes, and continuous improvement), which have been explained and discussed in chapter 2. Where relevant, references to available literature are made in the case study data. Following the examination of the case company, an examination of two of its first tier suppliers is presented. In the final section of this chapter the findings from the entire case study are discussed and interpreted.

The data description only contains relevant facts from the case study company and no comparative analysis with the other case companies is undertaken at this stage of the research (the analysis of all three cases is presented in chapter 8). The data are also not interpreted in terms of Simons' four levers of control model, since this will also be dealt with in chapter 8.

Table 7.1: Characteristics of Premium Car Co

	Premium Car Co
Market segment	Lower premium cars
Type of production	Production location
Annual production volume	80,000
Number of different models assembled	1
Number of employees	2,000
Factory location	Western Europe
Number of first tier suppliers	220
Major suppliers on-site in supplier park	Yes

Table 7.2: Interviews at Premium Car Co and its suppliers

Company	Interviewee(s) / *Activity*	Date
Premium Car Co	Quality manager	20 July 2004
Premium Car Co	Supply chain manager	18 November 2004
Premium Car Co	Production manager	18 November 2004
Premium Car Co	*Plant tour*	18 November 2004
Premium Car Co	Human resources manager	19 November 2004
Premium Car Co	Quality manager	19 November 2004
Premium Car Co	*Plant tour*	26 January 2005
Premium Car Co	Quality manager; Supply chain manager; Human resources officer	9 March 2005
Supplier 1	Quality manager	26 January 2005
Supplier 2	Quality manager; Quality engineer	26 January 2005

7.2 Relevance of Premium Car Co for the Research

In this section the research context of Premium Car Co is described. The extent to which increasing product variety and shortening product life cycles play a role for Premium Car Co is discussed first. Thereafter, the importance of quality management for Premium Car Co is explained.

7.2.1 Product Variety and Life Cycles

Premium Car Co offers its customers an enormous list of options to choose from. During the development of the car model it currently produces, the organisation was driven by the belief that offering more options would result in higher profits. This has resulted in a vast number of configurations for many components of the car. Basically, this lower premium car model rivals Premium Car Co's upper premium cars in terms of the number of configurations. The supply chain manager explained:

> *"We offer 470 different front seats for our customers to choose from. Our cars come with 104 different variants of mirrors, and in a total of 60 different body types."*

Some of these body types are only slightly different from each other. On the one hand this is a direct consequence of producing a 'world car' (i.e. one car model that is sold all over the world) because local legislation may demand certain adaptations to the car body, on the other hand it is a consequence of trying to cater to local design preferences as much as possible. Competing premium car makers usually choose not to cater to the specific tastes of local markets but instead design a car that complies with nearly all local legislations, while still maintaining an attractive design. By doing so, they greatly reduce the need for local adaptations to the bodies of their car.

If a customer of Premium Car Co orders a car with a certain set of options, he or she will also receive a user manual that is adapted to the specifics of the car. The supply chain manager told:

> *"A customer's car comes with one out of the total of 1,190 different user manuals, because the manuals are not only printed in many languages but they are also adapted to the specific car."*

So, while other car manufacturers would supply a standard manual that describes all possible options (also the ones that the customer did not choose), Premium Car Co does not want to confront a customer with an explanation of, for example, satellite navigation if he or she did not order this option. Premium Car Co's managers were agreed that this is unheard of for other lower premium cars.

A major problem is that Premium Car Co does not know exactly what the costs are of the complexity that results from customising the cars and all related products and services. The marketing department of Premium Car Co argues that the customers are willing to pay a premium for such a wide choice of options. However, nobody in the organisation knows exactly how large that premium should be. Some options are rarely chosen by a customer. For example, the customer can choose for bright red leather, although less than 1% of customers actually do so. The costs of having the red leather available for these few customers are very high. In some cases Premium Car Co does know the costs of customisation. The supply chain manager gave an example:

> *"The 1,190 different user manuals cost 18 cents each just to order them in the same sequence as the cars on the production line."*

So, with a production volume of 80,000 cars, this amounts to more than 14,000 Euros per year, and these costs are excluding any printing costs or other costs. Therefore, the management at Premium Car Co is currently questioning if highly customising the cars does improve sales to the extent that the additional revenues exceed incurred costs. In fact, Premium Car Co realises that the costs in some cases exceed the additional revenues. The quality manager gave an example:

> *"We offer a certain sound system as an option. However, since the introduction of the car model in 2001, not a single customer has bought that option."*

Therefore, Premium Car Co is now actually reducing the variation within the same car model. Only very recently, several premium car manufacturers have admitted that they will start reducing the number of customer options in order to reduce costs and manufacturing complexity (Kurylko, 2006a; Kurylko, 2006b; Meiners, 2006).

The need for reducing the variation within a car model has become all the more urgent because of the increasing number of car models. The quality manager is convinced that:

> *"The future is likely to be less mass manufacturing and lower volumes."*

This means that sales per car model will become lower and therefore also the number of potential customers for a certain option.

The management of Premium Car Co is also aware of the trend of shortening product life cycles, because the managers keep track of industry data. The managers have noticed that life cycles are especially becoming shorter for non-premium cars. The premium car brands are still able to sell a car model for a relatively long time. Although many competing premium car manufacturers are currently speeding up the process of replacing existing car models with new ones, Premium Car Co is trying not to replace car models quicker than it did in the past. The quality manager explained that:

> *"We feel that we do not have to follow that strategy. It all depends on the positioning in the market. After all there are also risks involved in the introduction of a new car model, especially with a world car like ours."*

However, during the year in which this study has taken place, Premium Car Co has witnessed a decline in sales of its car model that necessitates it to reconsider the planned life cycle. In the end, the consumer decides if a car model sells or not, and if consumers walk away after a number of years, the car manufacturer may have to pull forward the introduction of the car's successor.

The decisions of how many options to offer and when to introduce a new car model are both very difficult decisions. The quality manager summarised:

> *"Brand image is of course very important for cars in the premium segment. Car manufacturers in this segment believe that they have to update their models regularly and that they have to offer a wide variety of options to maintain the brand image."*

Premium Car Co clearly attaches more value to providing a wide variety of options than to introducing fresh car models every couple of years.

7.2.2 Importance of Quality Management

Management and improvement of quality has always been a key issue at Premium Car Co. However, the large number of variants of nearly all car components does not make it easy for Premium Car Co to maintain high quality levels. The quality manager told:

> *"Controlling the processes in the plant is becoming more difficult when the variation of cars on the production line increases. We offer our customers a long list of options to choose from and that increases the variation on the production line."*

One way in which high product variety complicates process control is by its influence on the use of robotics. Premium Car Co's management was agreed that robots have for years been very handy for all kinds of inspections but the current high variety of parts makes it nearly impossible to use robots for inspection.

Even though quality is a very important issue in the premium car segment, it is not easy for Premium Car Co to align it with the financial demands of its owner. Premium Car Co has to meet the targets that have been set by Premium Car Co's owner. Within these targets there is a strong focus on labour costs and overhead, which stimulates the different plants to produce more cars with fewer people. However, quality standards should not be compromised as a result of employee reductions. So, all plants have to strike a balance between reducing labour costs and maintaining the quality of products and processes. For Premium Car Co it is especially difficult to reduce the number of employees because its cars are complicated to assemble and its customers expect a premium car to be of premium quality.

The complexity of Premium Car Co's assembly process is partly due to the fact that premium cars contain more innovative and high-tech components than non-premium cars, but it is also due to the design of Premium Car Co's cars. The quality manager believes that:

> *"The main problem with our car is the fact that this car has not been designed for manufacturing, but for selling. So, the manufacturability of the car is somewhat poor."*

This influences both the costs of assembly, as well as the quality of the final product.

Another reason why quality management is perceived to be important at Premium Car Co, is the increase in the more emotional kind of quality issues. Traditionally, car manufacturing was mainly concerned with technical quality issues but in recent years the importance of emotional quality issues has increased enormously (Stoffer, 2006). Quality measurement systems provide good data about the technical quality of the cars. They make clear what is broken and therefore needs to be fixed. However, the things that are broken are the easy defects. The quality manager clarified:

> *"Engineers are enthusiastic about these defects and are always eager to solve them. It is much more difficult to improve customer satisfaction when the car has no physical defects. What a customer likes or dislikes is not as simple as a technical defect that engineers can fix."*

For example, a customer of Premium Car Co does not like her new car because it has no subwoofer for the sound system. Her car has no subwoofer because she did not order one. However, she feels that a premium car should have a subwoofer as standard and she therefore did not bother to order one. Another example of emotional quality, which is important in the premium sector, is the sound of a closing door. Premium Car Co's management feels that buyers of premium cars have certain expectations with respect to the sound of a closing car door. The sound of the door is believed to give a cue about the overall quality of the car. However, the ideal door 'clang' may not be the same everywhere in the world. Therefore, the quality manager believes that:

> *"We cannot live up to the expectations of each customer in each country. However, all customers expect the quality they are paying for."*

To deal with this kind of problems Premium Car Co has to manage the needs and expectations of the customer, which is very difficult because it builds a car for the whole world. The shift away from technical quality, towards the quality of customer experiences is in line with the findings of existing research (Phillips-Donaldson, 2006; Pine and Gilmore, 1999).

A final reason why the management of quality is important, and will stay important, is the introduction of a Sports Utility Vehicle (SUV) that will be assembled on the same production line as Premium Car Co's existing car model.

This means that two different cars have to be assembled from different components on the same line. In some cases the two car models have different suppliers for a part but to make processes easier, one supplier will supply its parts to the other supplier of the same part, which will bring both to the production line at the Premium Car Co plant. This shift from one to two car models will pose some challenges for Premium Car Co. The production manager sees the following challenges:

> *"A key issue for us will not only be to reduce the number of suppliers for the two car models we will produce, but also to harmonise the way parts are bolted on the two car models."*

The latter challenge means that the differences in the designs of the two cars also have consequences for the way the cars are assembled (e.g. a bumper can be mounted on a car in several different ways). Cooperation between the engineers and designers of the different car models is necessary to reach standardisation of processes, eliminate waste, and prevent defects.

A consequence of assembling a second car model on the same production line is also that the link between a product and its assembly process becomes weaker. In the past, Premium Car Co would dedicate an assembly process to one product, while now processes have become more generic and therefore suitable for multiple products. This decoupling of products and processes also means that processes can last longer than products in terms of their respective life cycles (Noori, 1991; Boynton and Victor, 1991).

7.3 Customer Focus

In this section Premium Car Co's focus on the customer is discussed. The most important issue for Premium Car Co are the expectations of its customers (i.e. what do they expect from their new car?). This issue is dealt with in the remainder of this section.

7.3.1 Customer Expectations

Premium Car Co nowadays is very much focused on the expectations of the customers regarding their cars. In the past Premium Car Co would attach much more value to the views of its own engineers. A major change took place at Premium Car Co when it started listening carefully to the voice of the customer. The quality manager explains that:

> *"In the past the focus had been too narrow on engineering and costs. With the introduction of our current car model, we realised that customer satisfaction could be increased substantially with only minor consequences for production costs."*

For example, the introduction of an extra cup holder increased customer satisfaction significantly, while the additional costs were low. The Premium Car Co managers were agreed that this kind of improvements can never be realised if the focus is only on costs. However, Premium Car Co also learned that listening to customers is not as easy as it may seem. When Premium Car Co first introduced the cup holders customers were still not satisfied because the cup holders were too small. Premium Car Co had only taken into account small cups, while in practice many customers wanted to use them for larger cups and small bottles.

Although the extra costs for the cup holders are presumably small, actual data on costs of parts and logistics are difficult to gather for Premium Car Co. However, given that Premium Car Co offers its customers a wide variety of options to choose from, the managers feel that it would be a good thing if the total costs were taken into account. What are the costs of offering customers a wide variety of options to choose from? What are the additional costs for supplies if product variety is large? It is important for Premium Car Co's management to have a reliable answer to these questions before offering yet another option.

Premium Car Co has learned that it is important to stick to the following two rules:

1. The customer determines quality, not the engineers.

2. Never lose sight of finance.

Even though Premium Car Co has made great improvements in listening to the customer, the management still feels that it needs to do more. The quality manager explained that:

> *"We still have a long way to go to catch up with the best in class. Toyota is better in taking the customer perspective into account, especially at the moment of launching a new car model. We need to make many more adjustments to our cars than Toyota after the initial launch of the cars."*

A complicating factor for the Premium Car Co plant, with respect to listening to the customer, is the fact that it does not only have consequences for the production process but also for the car dealerships. Premium Car Co dealerships should be able to fix their customers' problems at once and for 100%. If this is not the case, the customer will be more dissatisfied than he already was because of the problem he has with his car.

Premium Car Co has several ways to obtain information about customer satisfaction issues with its cars:

- Once a new car model has been launched, Premium Car Co calls customers to ask about their experiences with the car. The customers are called after they have had the car for one month, in order to capture all start-of-life issues. One goal is of course to learn from the defects that the customer is experiencing but another goal is to get a better understanding of the customer's perceptions of the car. An example is the customer's perception about fuel consumption of the car. Fuel consumption in practice is higher than what is presented in car brochures and advertisements. If a customer does not know that the figures presented in brochures are obtained during laboratory tests under special (i.e. non-realistic) conditions, this can dissatisfy the customer.

- Premium Car Co organises dealer clinics, which means that the customers of one dealership are brought to the plant to show them where and how their cars have been made. During these clinics Premium Car Co can obtain valuable information from the customers.

- The whole Premium Car Co organisation makes use of an internal fleet of Premium Car Co cars that are driven by its managers. These managers can then report issues they have with the cars. However, it might be a problem that the managers are not representative for the normal customers.

- Premium Car Co undertakes product audits, which basically mean looking at the car through the eyes of the customer. Premium Car Co auditors in the plant check a car to assess if it can meet customer expectations. These auditors are very good in assessing functional issues but not so much in determining the perceptions of a new Premium Car Co customer who used to drive a competing brand.

- J.D. Power and associates is a US based firm that conducts surveys among consumers about products they have bought. This firm also asks consumers about their perceptions of the cars they own. The results of these surveys are published and can be used to compare different brands and types of cars. Premium Car Co uses these surveys to compare its performance to the performance of the competition.

- Premium Car Co also uses benchmarking as a tool to compare itself with its competitors.

Although all these sources of information about customer satisfaction issues are very useful, Premium Car Co's management was agreed that it is still very difficult to incorporate the information into the production process. The quality manager told:

> *"What is needed is something more than just ticking boxes. It is critical to understand what the customer really wants and how these wishes can be fulfilled by changing something in the production process, or in the design or engineering of the car."*

The aforementioned example of the ideal sound of a closing car door indicates that it is difficult to capture customer expectations. It is very difficult to determine when the sound of the door is in line with expectations. Even when Premium Car Co knows that the sound is not right, it is very difficult to tell what needs to be changed in the design of the door to achieve the right sound. Premium Car Co has recently started an in-depth study into this specific issue.

Quality function deployment (see Mizuno and Akao, 1994) has been used by Premium Car Co to align organisational characteristics with customer needs but the problem is still that customers have different needs and perceptions all over the world. Premium Car Co sells nearly 50% of its cars in the USA, over 40% in Europe, and the remaining cars in the rest of the world. Therefore, it will always be difficult to build a world car that caters to everybody's needs.

Knowing all the needs and wants of its customers is also not enough for Premium Car Co because it does not help the organisation to win new customers. The quality manager explained that:

> *"It would be more interesting for us to know the opinions of people that do not buy our cars but instead go to our competitors. Why do they not buy our cars?"*

This question is very difficult to answer for Premium Car Co.

Although Premium Car Co is now paying much more attention to customer needs than it used to do in the past, it still has to deal with its legacy of its previous engineering focus. When the management of the Premium Car Co plant wants to scrap unpopular options from the options list in order to improve profitability, it has to make a case to the top management of the whole Premium Car Co organisation. However, this is not easy since they have to indicate how much money would be saved if a certain option is scrapped from the options list. The supply chain manager told:

> *"In most cases the costs savings are very small because we are dealing with an ongoing car model. So, the investments in development of the option and in acquiring the necessary tooling have been made already."*

The only costs that can be saved then are the direct costs of the component itself, but these are most likely offset by the price that the customer has to pay for the option. Therefore, it is difficult for Premium Car Co to make a strong case for scrapping certain options when the car is already in production. It is much easier to argue that a certain option should not be available on future car models because then also the development and tooling costs can be added to the total savings. However, this means that on the short term not much will change. A problem with removing options from existing car models is also the risk that customers may complain if they want an option that is not available anymore, although the same reasoning may apply to customers that trade in their old Premium Car Co car for the latest model. In any way, there are options that are chosen by customer so rarely that they could be removed from the options list without consequences.

The consequences of offering many options are different for different markets. Offering a large product variety is especially problematic in the USA, which has a different car market than Europe. The supply chain manager explained that:

> *"In the US car dealers have a large stock of cars, and customers buy cars from stock. Customers want their car immediately when visiting a dealer. They do not want to wait, but they want to drive away the same day. This requires a different approach compared to Europe."*

So, for the US market Premium Car Co builds cars to stock. This means that Premium Car Co dealers cannot have every possible combination of options available on the cars that are in stock, otherwise the stocks would have to be enormous. For some competitors in the premium segment this is not a large problem because they will only offer their cars with nearly all options fitted. This does not only make it easier to build the cars but also to manage the supply chain for the US market. Still, Premium Car Co does not follow this strategy because offering only cars with many options will raise the price of the cars.

Premium Car Co also aggravates the product variety problem by the way it uses its dealerships. Many car manufacturers shift part of the customisation of the car to their dealerships but Premium Car Co tries to do it all before the cars leave the factory. The quality manager gave an example about alloy wheels:

> *"If customers choose alloy wheels, most car manufacturers will just ship the cars with steel wheels to the dealerships and then let the dealerships fit the right wheels. Our cars always leave the plant with the right alloy wheels fitted before shipping the car to a dealership because we want to have the revenues of the alloy wheels instead of leaving them to the dealerships."*

From a revenue point of view this may be a sensible policy but, given the complexity that it causes during the assembly process and the delivery to the dealerships, costs may exceed the additional revenues.

7.4 Variation Reduction in Organisational Processes

In this section the developments that have taken place at Premium Car Co to control the organisational processes are discussed. The major factor in relation to organisational processes is the risk of poor quality. Relevant processes for Premium Car Co are planning processes, production processes and purchasing processes. These issues are dealt with in the remainder of this section.

7.4.1 Planning Processes

Premium Car Co's management admits that planning processes are not very well developed in the organisation. This was already the case in the past, but the problem has become worse now that manufacturing has become more complex and life cycles are becoming shorter. The supply chain manager explains:

> *"Our organisation wants to achieve and it has great ideas for improvement but it does not prepare and plan properly. Even after the start of production, we will change 40 to 60% of the car, while for example Toyota will change about 4%."*

The poor planning that causes such large percentage of change is not only related to the production planning. To a large extent it is the result of the fact that Premium Car Co's cars are designed to sell and not so much to be built, which means that assembly costs are higher than they could be. Premium Car Co's management now realises that this will have to change to survive on the long run. The quality manager told that:

> *"We are obviously not very happy with that but the situation is improving with the design of new models. The production costs should be in the minds of the designers and engineers when developing a new car model."*

Although Toyota has a large lead over Premium Car Co in this respect, it still sees much room for costs savings by improving the design of its cars (Treece, 2006a).

Another example of Premium Car Co's poor planning is the way in which the internal and external logistics for the current car model were outsourced. An external logistics provider was contracted by Premium Car Co to do the external logistics. Just six weeks before the start of the production, Premium Car Co asked that same company to also do the internal logistics. However, this company had no experience at all with internal logistics. Still they managed to be ready for it in time. Premium Car Co's management were agreed that this example is typical for the way Premium Car Co works. The Premium Car Co people seem to be great fire-fighters. As a result of the fire-fighting skills of its employees, Premium Car Co has in fact a higher percentage of cars rolling out of the factory in the right sequence than the industry benchmark Toyota. No less than 95% of Premium Car Co's cars are produced in the right sequence. If a car has to be taken off the production line because there is a problem with it, Premium Car Co will just swap that car with a similar car that is still at the beginning of the production line, in order not to disturb the sequence of finished cars.

This all is not to say that Premium Car Co cannot plan at all. In fact, when the current Premium Car Co plant first started assembling cars for Premium Car Co, it had to go through a tremendous change process. The plant employees were used to high-volume production of low-cost cars with little product variety and low manufacturing complexity. Moreover, the plant did not have a good track record with respect to the quality of its cars. So, there were serious doubts with the management about the capabilities of the employees, and it was an enormous challenge to convert the plant into a manufacturer of low-volume premium cars, which are highly complex and should be of high quality. This required a large scale planning effort from the whole organisation, which it completed successfully.

Apart from a large cultural change, the Premium Car Co plant also needed changes to its processes. Therefore, quality systems and lean processes were put in place. However, it was difficult to make all employees accept these changes and use the systems and processes.

Because of the higher complexity of the Premium Car Co cars compared to the previous non-premium cars, the takt time (i.e. the time between the completion of two consecutive cars) of the production line went from 40-45 seconds to 80 seconds. So, employees now have more time to complete the more difficult and varied tasks on the cars that go down the production line. To the employees this felt very strange at the beginning because their managers had always told them that the plant had to close if the projected production volumes would not be reached. The human resources manager told that:

> *"In the past, the only thing that mattered for the plant was production volume. With the start of the new car, quality became the most important issue. The employees found that really hard to believe because they had been beaten for years to produce enough volume."*

Another issue that needed attention was the discipline of the employees. The human resources manager explained:

> *"The employees tend to be innovative and inventive but not very disciplined, which means that they will not do the same thing over and over again. Instead, they will try to find shortcuts."*

An area where this is particularly visible is preventive maintenance of equipment. This is usually quite boring work and will therefore be the first thing that is skipped if there are many things to be done. The Premium Car Co managers were agreed that developing the maintenance plans is done very well but the execution is rather poor. An example that the human resources manager gave, is the preventive maintenance of a production robot. In other plants the maintenance would be carried out at the right time and according to plan, to prevent failure of the robot. However, if the robot does fail, they would find it hard to get it fixed. In Premium Car Co's plant the same robot would not receive proper maintenance and would eventually fail. However, once it fails the employees are very capable of fixing it in an inventive way. The human resources manager summarised:

> *"The employees like the unusual events more than the every day routines because the unusual events require them to be creative."*

This lack of discipline becomes clear when a formalised production system is used throughout the plant. Premium Car Co uses a production system developed by its owner, which they admit to be, to some extent, a copy of lean manufacturing. It requires standardisation of processes and achieving a high level of repeatability, which are both problematic for a workforce with little discipline. The management explained that it turned out that the Premium Car Co employees did everything their own way. For example, bolting the wheels on the cars was done by different employees in different ways. Therefore, Premium Car Co started three years ago with an initiative to film the employees while they were doing their tasks. If different employees would be filmed while they were doing the same task, their ways of working could be compared. It became very clear from the footage that there were large differences between the ways of working of different employees. The employees then discussed with each other why they did it their way and from that a standard best practice could be developed. The human resources manager clarifies:

> *"Obviously it requires a great deal of trust between the employees and the management to be able to use this video approach. The fact that it is the employees' own time they are saving when they improve, makes it easier for them to adapt a different way of working. However, in the end both the employee and the business have to benefit from the improvements."*

Although the video approach was successful, Premium Car Co has not used it anymore for several years but it is now starting to use it again. This pause in the use of video has not so much to do with the approach itself, but more with external factors like the growth stage the plant is in.

7.4.2 Production Processes

Responsibility for the production processes at Premium Car Co has over the years shifted to the shop floor employees. In the past they would be much more controlled by the management, while they now are more empowered.

The Premium Car Co plant is currently organised in work groups of six to eight employees. All work groups have a supervisor and they have clear objectives in relation to production volumes, quality and safety. The work groups also have to pay attention to the situation of their people (e.g. holidays and problems at work).

In the past the shop floor employees were not accountable for these issues. The objectives for the work groups are simply the result of cascading higher objectives down the hierarchy. The production manager told that:

> *"At the top of the organisation objectives are set, which are broken down for each hierarchical level until they reach the work group level."*

Premium Car Co does not set objectives for individual employees. On a weekly basis all objectives are monitored and the different work groups also compare their performance to last year's performance.

The work groups are the smallest units in the production process. Several work groups together form a production zone. During the production process cars are quality checked when they go from one production zone to the next. Other quality checks take place at the end of the production line, when the cars' systems are checked. Thereafter, the quality department checks the quality of the complete car. If a defect is found during these quality checks, the action to be taken depends on the number of defects found. The production manager explained that:

> *"If there are few defects, the employees can solve them; but if there are many defects, a more senior person has to be involved. The more defects found, the higher the problem has to be taken up the hierarchy."*

The defects found are traced back to the individual employee. If the defects are related to suppliers, Premium Car Co will have a talk with them about the defects. The production manager does not make a strong distinction between Premium Car Co's own employees and employees of suppliers. He told that:

> *"I do not see much difference between talking about a defect to my own employees or to a supplier."*

In both cases the same processes and procedures are in place for dealing with problems and defects. However, these processes did not appear to be very structured, although it would be pointed out to responsible employees what had in fact gone wrong.

In the whole production process there are not many preventive systems and procedures in place. Once a car is finished and it comes off the production line, many checks and tests are conducted by Premium Car Co. The focus is very much on curing quality problems, instead of preventing them. During plant tours, we have seen inspection employees hit some part of the car with a hammer because it was 'not properly aligned'. The employees claimed that this was nothing special and that the loud noise was caused by the type of hammers they used and not so much by the force they were applying on them.

At the end of the assembly line there was a parking place with finished cars. The employees told that these cars would get additional inspections because they were for the Japanese market. This is done because it is very costly to ship a car with defects back from Japan to Europe. Still, it is remarkable that they do these inspections only on cars for the Japanese market. The inspections show that Premium Car Co wants to prevent that any car leaves the plant with defects, especially when that car is for a quality-conscious Japanese customer. Obviously this is a very commendable aim but when quality is predominantly achieved by end-of-line inspections it may be rather expensive to reach that aim. Another indicator that Premium Car Co is focused on curing quality problems is its habit of test-driving every finished car for ten to twelve kilometres, and some cars even for more than 30 kilometres. This seems to be a rather long distance, which requires Premium Car Co to employ five full-time test-drivers.

Premium Car Co's management argued that quality checks during the production process are also costly and Premium Car Co saves money on these checks, which it can use for the end-of-line inspections. The quality manager argued:

> *"A consequence of eliminating quality inspections is the need to build quality checks in the production line. If we would do more quality checks during the production process, this would mean that the production process would take longer, which is in itself also a cost. So, the aim is to strike a balance between doing checks during the production process and inspecting the cars at the end of the production line."*

A reason why Premium Car Co's management feels it needs to rely on many quality inspections at the end of the line is the fact that the rather low manufacturability of its cars makes it difficult to check quality during the assembly process.

Apparently, the quality inspections work very well for Premium Car Co, even in today's environment, because the plant has been awarded a contract to manufacture an SUV for another brand of Premium Car Co's owner. Premium Car Co's managers were agreed that their plant is now regarded highly by their owner, who wants to build other cars to the same (quality) standards as the Premium Car Co car model. Premium Car Co's managers regard it as a compliment to the Premium Car Co employees that their plant is chosen for other car models. At the same time, they are aware of the need to initiate more organisational changes and keep working on the management of quality.

One of the reasons Premium Car Co feels that it needs to keep working on the quality of its cars is the growing electronics and software content. In the entire automotive industry, electronics and software constitute a growing share of the value of a car. In 1990 about ten percent of a car's value was represented by electronics, while this is expected to grow to forty percent in 2010 (Sherefkin and LaReau, 2006). Consequently, many quality problems with cars are nowadays caused by electronics. Huhn and Schaper (2006) wrote:

> *"High-end models from German and Japanese automakers use 65 to 100 electronic control units (ECUs), making each vehicle a real-time computing network requiring extremely high reliability. Unfortunately, embedded software has, at best, a varied record of quality: newspapers regularly report failures and recalls."*

Many electronic parts are manufactured by only a few suppliers and they are used by all car manufacturers. However, not all car manufacturers experience the same level of quality problems with electronics. Premium Car Co's human resources manager has an explanation for this:

> *"The parts themselves are not different between different car manufacturers. Still, some car manufacturers have worse problems with electronics than others. This has mainly to do with the way the electronics are used and the way the employees at the car manufacturers install them into the car."*

So, the first cause of problems with electronics is the way the car manufacturers use the possibilities that the electronics offer to them. The human resources manager told that some car manufacturers used the electronics for voice interaction between the car and the driver. He believes this has caused many problems and this approach seems to have been abandoned altogether now. The second cause of electronics problems is the way they are assembled into the car. The human resources manager is convinced that this causes the majority of problems with electronics:

> *"The employees at the car manufacturer do make a difference, even when the same components are used. Employees can feel if something went wrong during assembly. The question is if they will report it. That makes the difference."*

Premium Car Co's management believes that it has inventive employees who are capable of dealing with unexpected problems. The commitment of the employees to solve problems is very high and quality inspections prevent problems that have been caused during the assembly process from reaching the consumer.

7.4.3 Purchasing Processes

Premium Car Co works with approximately 2,500 part numbers (not taking into account all the variants), while the best-in-class manufacturers use about 1,800 parts, according to Premium Car Co's management. The complex parts are outsourced in modules or systems, while many other parts are bought from commodity suppliers. Modularity has been a development of the last couple of years, which helps to move the complexity up the supply chain towards the suppliers. The supply chain manager told:

> *"The idea is to give the complexity away to the suppliers and thereby the problems also move towards the suppliers. Thereafter, they can then be managed with a stick."*

Premium Car Co can manage its suppliers in this way because it has power over these suppliers, not only as an individual brand, but also as part of the global car manufacturer that owns Premium Car Co. Suppliers can win or lose high-volume contracts from other divisions of Premium Car Co's owner, based on their performance towards Premium Car Co.

In the present situation, the delivery of parts to Premium Car Co by its suppliers takes place on average three times per week. In general, Premium Car Co keeps a stock of supplies of a half to one day. On top of that there is always about one day of supplies in transit to Premium Car Co. So, together that means a buffer of about two days. A decade ago, the current Premium Car Co plant would not have any Just-In-Time (JIT) delivery processes in place, but would instead rely on large warehouses for supplies. However, the mentality at Premium Car Co is still the one that was appropriate in the pre-JIT era because employees do not seem to be very worried if suppliers do not deliver their products on schedule. If supplies are too late, the fire-fighting skills of the employees are believed to be sufficient to solve the resulting problems. The supply chain manager noticed that Premium Car Co deals completely different than, for example, Toyota with suppliers that do not deliver their supplies on time. The manager told that:

> *"If suppliers of Toyota are 25 minutes late, they get a call from Toyota. However, if this happens to us, people will just say that it is the problem of the supplier and not our problem."*

Similarly, Premium Car Co does not put much pressure on its suppliers to improve the traceability. Before 1989 all supplies to the plant were shipped in cardboard boxes. Then they changed to plastic boxes that can be reused. However, the plastic boxes are not always labelled properly by the supplier (the label may have fallen off, or the box may not have been labelled at all). Therefore, Premium Car Co re-labels every box that arrives in order to achieve traceability of supplies. Although traceability can be achieved this way, Premium Car Co has to put efforts in it and bear the costs. The management believes that they could solve this kind of problems if there were a disciplined continuous improvement approach that focuses on small and gradual improvements. However, they feel that their organisation is only capable of the more radical changes.

Given the fact that Premium Car Co does not complain to its suppliers about the problems described above, the relationship between Premium Car Co and its suppliers is good. The suppliers know what is really expected of them, and Premium Car Co keeps them informed about their performance electronically. Premium Car Co deals with its suppliers in the following way:

- Production schedules are sent to the suppliers every day. These schedules contain a plan for the next ten days.

- Several measures are used to measure the performance of the suppliers (e.g. quality and delivery performance). Suppliers lose points if they fail on these measures. If that happens too often, suppliers risk losing their preferred status for Premium Car Co and its owner, which means that these suppliers cannot be awarded new contracts by any brand of Premium Car Co's owner.

- Premium Car Co has reduced the number of over-supplies that suppliers sometimes sent to Premium Car Co in the past. Over-supplies are supplies that are in excess of the number that Premium Car Co actually needs for its production. Suppliers know that Premium Car Co will need the same supplies later on, so shipping many supplies in one truck is efficient for suppliers because it reduces the number of shipments. However, it is inefficient for Premium Car Co because it has to store the over-supplies and later on retrieve the supplies from its warehouses. Several years ago, about 20% of suppliers would regularly ship over-supplies. Today, this has been reduced to about 5% of suppliers.

- Premium Car Co has approximately 220 first tier suppliers. About 200 are from the whole of Europe, while the remaining 20 suppliers are situated outside Europe.

- The most important suppliers are situated in the industry park next to the Premium Car Co plant. These suppliers manufacture various parts (e.g. instrument panels, doors, bumpers and seats), which they deliver directly to Premium Car Co's production line in the right sequence. A 12-hours sequence, which is 100% fixed, is used by both Premium Car Co and its suppliers in the supplier park. The suppliers that are not situated in the supplier park do not deliver their supplies to Premium Car Co in this sequence.

Although it seems that suppliers could perform better (in terms of shipping on schedule, no over-supplies, and using the right labels), Premium Car Co's management realises that part of the blame is on them. As said before, Premium Car Co does not stick very well to its (production) planning and it takes pride in its high level of flexibility. However, the management feels that as a consequence of this, Premium Car Co pays a premium for its supplies. The supply chain manager explained:

> *"Suppliers know that we can change our planning several times before fixing the actual production sequence, and they therefore charge us a premium for our supplies of up to 20%."*

Just after a new car model has been introduced, Premium Car Co will implement many new ideas and concepts, which means that many supplies need to be modified during the same (short) period of time. Even though the Premium Car Co' management is confident that the employees always make it in the end, the costs may be high.

On top of the price premiums that suppliers may charge Premium Car Co for its deviations from its own planning, modifications also result in other costs. Supplies can be under way for quite a long time. So, if Premium Car Co changes its plans, it has many supplies coming its way that it does not really need anymore. Storage space is not really a problem at the Premium Car Co plant, since the warehouses that were used in the past (before JIT delivery) are still there. The supply chain manager told:

> *"Our people will just store all unneeded supplies in warehouses but they neither record which supplies are stored, nor the quantity of them. Consequently, after some time nobody knows what is exactly stored in these warehouses."*

So, in terms of supply chain management, Premium Car Co's management is aware that more improvements can, and should, be realised.

7.5 Continuous Improvement

In this section Premium Car Co's efforts to achieve and maintain a culture of continuous improvement are discussed. Developments that have had an influence on continuous improvement are explained. The major factor underlying these developments has been the need to more closely involve different parties (e.g. management, employees and suppliers) in the process of continuous improvement. Relevant issues for Premium Car Co are process improvement, improvement of employee knowledge and skills, and supplier improvement. These issues are dealt with in the remainder of this section.

7.5.1 Process Improvement

Premium Car Co's management understands that it needs to continually improve its processes in order to stay competitive in the market place. One way they do this, is by stopping the production line every day for five minutes to discuss the 'issue of the day'. Premium Car Co tries to generate discussions among the employees about important issues. Therefore, five important issues have each been assigned to a day of the week in the following way:

1. Monday: safety
2. Tuesday: quality
3. Wednesday: costs
4. Thursday: production volumes
5. Friday: people

Every day all employees are encouraged to talk about the issue of that day, but it is not clear what concrete improvements have resulted from these discussions.

Apart from these discussions about the issue of the day, which are without obligation, Premium Car Co has also started to focus on improvements that have a more profound impact on the employees. Improvement also means that costs have to be reduced continuously. Therefore, Premium Car Co has started, in recent years, improvement projects aimed at costs savings, in order to stay competitive. For example, during the last couple of years, the production department has been generating costs savings of 9% – 10% per year. In practice, this means that every year more than 50 people have to leave the production department. The selection of these 50 people is left to the work groups. The production manager told:

> *"The demands are cascaded down the organisation to the work groups, because they should generate the actual savings. The work groups have to come up with advice on how to reduce the number of employees needed to accomplish a task."*

The production manager claimed that the employees in the work groups do not have problems with selecting the employee that has to leave their group, even though the work groups are small teams (i.e. six to eight people) of closely cooperating employees. Apparently, all employees are aware of the need to reduce costs in order to safeguard the future of the plant. The reductions in manpower and costs are realised by taking out waste from the processes and activities. The work groups use kaizen tools to achieve this (see Imai, 1997). Once the work groups have realised the necessary reductions of employees, Premium Car Co needs to find a way to make the redundant employees leave. Premium Car Co can offer them severance packages (e.g. early pension) or, if possible, reposition them somewhere else in the organisation.

The responsibility for process improvements is not only the job of the shop floor employees. The management of Premium Car Co also looks at what it can contribute to improve processes. One way the management thinks it can contribute, is by cooperating with other brands of Premium Car Co's owner, to realise more integration between different car models and make more use of common parts. Given the decreasing production volumes for individual car models, the management of Premium Car Co's owner has in recent years indicated that using common parts should be a priority for the future. Until now, there have been few successful initiatives at Premium Car Co's owner to make use of common parts, so in practice not many parts are the same between different car models. For example, Premium Car Co's owner tried to commonise parts between a Premium Car Co model and another model but this was no success at all. The human resources manager told:

> *"In the end only four parts were the same between these two car models."*

So, apparently making use of common part is not very easy to realise. However, Premium Car Co expects future models of its own brand to have more parts in common. But this will only be realised for the models that arrive after 2010. One of the reasons why using common parts has not been very successful at Premium Car Co, is the management's belief that it is not a critical issue for Premium Car Co. The managers were agreed that common parts will bring costs savings during production of the car. However, they also told that Premium Car Co is a premium brand and the argument about premium cars is always that customers are willing to pay a higher price for a distinctive car. So, common parts should only be used where they are not visible to the customer. The engine is such a part and therefore Premium Car Co uses diesel engines that have been developed in cooperation with another car brand. This increases the production volume of these engines and thereby lowers costs for both parties. To make sure that these diesel engines run and perform in a way that suits a premium car, they are tuned specifically for Premium Car Co. So, in the end the engine characteristics are different between the engines for the two brands, although the basic engine architecture is the same.

The management of Premium Car Co believes that the design of the production processes can be improved as well. The Premium Car Co plant makes use of robotics during the production process, in particular for the assembly of engines and car bodies. In the future, the management expects the use of robots in these areas to increase even further. With respect to the car bodies, it is mostly the welding and painting that is automated. The human resources manager explained:

> *"For welding, robots are a necessity because welds need to be consistent, which is very hard to achieve by hand."*

The trim and final assembly department is the least automated. The management is aware that decreasing batch sizes demands that robots become more flexible. This is a big challenge for Premium Car Co because it will increase the complexity and therefore increase the risks of defects and downtime. Because of this development, the management is also reconsidering the extent to which the trim and final assembly department will make use of robots in the coming years. The human resources manager argued:

> *"Not everything needs to be done by robots because in some cases a robot is doing a task that can easily be done by an employee without a high defect rate. It is of course important to reduce defects as much as possible, but robots are very*

> *costly and therefore engineers may choose to have certain tasks done by hand."*

Premium Car Co currently already has fewer robots in the trim and final assembly department than many competitors, because of the variety in products. Another issue that influences the extent to which robots can be used during the assembly process, is the design of the car itself. This comes back to the design for assembly issue. The quality manager is convinced that:

> *"Design plays a major role in the car industry and many problems can be prevented during the design phase of a car model. Toyota is very good at this and at least part of Toyota's success is the result of its management of the design phase."*

An example that indicates that robots are not always the best solution to solve a problem, is an experience that Premium Car Co's owner had in a European engine plant. In this plant they had a situation in which the basic engine block had to be moved to the part of the assembly process where it would be built-up further into a complete engine. Premium Car Co's owner used automatically controlled vehicles (ACVs) to bring the engine block from the end of the first production line to the next production line where the engine block would be assembled into a complete engine. One robot was used to put the engine block on the ACV and once the ACV had arrived at the other production line, another robot would take the engine block from the ACV. However, during the transport of the engine block on the ACV to the second production line, the engine block would move slightly because of vibrations and movements of the ACV. Therefore, the second robot had difficulties in determining the right positioning of the engine block when it put it on the production line. To solve this problem, Premium Car Co's owner developed an expensive system that helped the second robot to determine exactly the positioning of the engine block when it arrived on the ACV. So, the robot could then position the engine block exactly right on the production line. However, when managers of Premium Car Co's owner visited a plant of a competitor to look at their processes, they saw that they had solved the same problem in a much cheaper way. They had just made a wedge on the floor of the plant at the beginning of the second production line. So, the ACV would drive onto the wedge, which made the engine block slide into the right position and two arms would guide it onto the production line in the exact right position. This was a much simpler and cheaper solution that worked just as well as the expensive solution of Premium Car Co's owner.

Process improvements are a necessity for Premium Car Co, simply because its owner demands them. In recent years, the Six Sigma improvement method (see for example Bhote and Bhote, 1991; Pande et al., 2000; Pyzdek, 2003) has started to gain momentum within the organisation of Premium Car Co's owner. Currently, all brands need to generate financial returns and quality improvements by means of Six Sigma projects. The quality manager told:

> *"We have one master black belt and ten black belts, and 130 green belts are being trained at the moment. The black belts are working on projects of cross-functional problems. The green belts will work on smaller projects."*

Premium Car Co uses a standard six panel DMAICR approach (Define, Measure, Analyse, Improve, Control and Report; see Senapati, 2004) for its Six Sigma projects. The 'define' and 'measure' steps are found to be the most difficult for Premium Car Co.

Also in a much broader sense, Premium Car Co pays attention to improvements. These days, environmental issues like the use of water and electricity receive a lot of attention. With respect to employee well-being, there are now systems in place for the benefit of the employees: for every job a safety risk assessment is made, and assessments are made for employees who have to lift things during the production process.

7.5.2 Improvement of Employee Knowledge and Skills

As explained before, the Premium Car Co plant has in the past assembled cars for another brand of Premium Car Co's owner. During those years, the quality performance of the plant was poor and, consequently, major improvements had to be made in the transition to a Premium Car Co plant. In these improvement processes, the employees have played the most important role. The production manager described the old situation at the plant as follows:

> *"Some ten years ago the situation at the plant could be characterised as poor quality, poor production volumes and*

poor morale. The consequence was that the plant was not a nice place to work."

In 1998, the management of the plant and the labour unions collectively agreed to change the relationships and way of working. It was felt by all parties involved that it would be better for the plant if all employees tried to improve the plant together instead of leaving the improvement efforts only to the management.

Consequently, every employee in the organisation went on a two-day workshop that aimed at a culture change with respect to the way people work with each other in the plant. Management and employees should not be suspicious of each other anymore but cooperate. This approach proved to be rather successful. The production manager told:

"Although few people actually believed this would work, it had positive results. Things started to change and it was felt that the plant could start from a new beginning."

Of course not all employees in the organisation were willing or able to make the change and they therefore left the organisation. New employees who had not been part of the plant's history entered the organisation to replace the ones who left. The management realised that communication was the key issue at that point in time. The negative situation at the plant had to be changed before the actual start of the production of Premium Car Co cars.

The management team also changed during those years because Premium Car Co's owner brought new managers to The Premium Car Co plant from all over the world. These managers were willing to drive the change process. It was felt that this was necessary for the future of the plant. Moreover, the intention was to make the Premium Car Co plant into a show case within the wider organisation of Premium Car Co's owner.

Since the development time of a car is three to four years, the decision in 1997 to build cars of the Premium Car Co brand at the plant meant that production would not start before 2001. The production of the previous car model was ceased in 2000, which meant that the Premium Car Co plant had one year to prepare for the start of the the new car model. This time was not only used to train the employees, but also to work for the city where the plant is situated. The employees were sent out to do support activities for the local community (e.g. painting). The human resources manager explained:

> *"There has always been a relationship between the plant and the local community. If the plant had bad times, then the community would also have bad times because of negative effects on spending. So, we were always blamed when times were tough in the city."*

Many people who live in the city where Premium Car Co is situated have worked at the Premium Car Co plant or are still working there. To improve the impression about the plant amongst the general public in the city, the Premium Car Co plant sent its people out into the community to do good things. Apart from doing something back for the community, these activities were also good team-building exercises for the employees while there was no production in the plant.

Just before the start of the production of the Premium Car Co cars, a country-wide study had been conducted that found alarmingly low levels of literacy and numeracy, as well as non-existent computer skills for people working in the manufacturing area. This came as a bit of a shock to the Premium Car Co management because it was very important for the assembly of the Premium Car Co cars that employees could read, work with computers, and work with for example statistical process control. Therefore, all employees were sent to a training program. The management had to announce this training program very carefully to the employees. The human resources manager explained:

> *"Of course we had to prevent that the employees felt they had to learn to read again, because it would make them feel stupid. Therefore, the training course was presented to the employees as necessary to acquire new skills for the advanced cars they were going to assemble."*

It soon became clear that the problems at Premium Car Co were not as big as elsewhere in the manufacturing industry. During the first course 400 employees were educated and they completed two weeks' course work in just two days. So, these employees were clearly brighter than the average employee in manufacturing. The management believed that, to some extent, this can be explained from the fact that employees at the Premium Car Co plant had been over-paid and over-qualified in the past.

Training of employees has remained a priority for Premium Car Co in the years since it took over the plant. The employees that were unable to change had left the organisation anyway, so the remaining employees were the ones that were capable and willing to change. All managers were agreed that with the help of the employees major improvements have been realised. The human resources manager told that:

> *"Good communication has been essential in the whole change process. The change of organisational structure into the work group structure, training of employees, and learning from mistakes instead of punishing employees have all contributed to the positive changes that have happened at the plant."*

Premium Car Co's management feels that still many improvements can be generated, both by the employees and for the employees. Some improvements indicated were:

- Working on continuous improvement and removing waste. Making the employees to look at their processes from an improvement perspective.

- Making use of the knowledge of the experienced workforce on the shop floor.

- Reducing the complexity of the assembly process.

- Making the employees and lower management to understand that they can only drive the business by driving the processes.

Developing a quality culture in the organisation remains a challenge for Premium Car Co. The employees need to have a quality mindset but, as indicated before, historically the Premium Car Co plant was not known for high quality products. The management felt that accountability and empowerment of the employees needed to become a reality. The quality manager explained that:

> *"It was clear that a formal quality approach was needed that gave employees the responsibility for their own jobs. This should not just apply to the managers in the organisation, but to each employee on every level. Standardisation of processes and activities was needed as well."*

Premium Car Co's owner then came up with a managerial view of the quality culture problem and it realised that a system like Toyota's production system (see Ohno, 1988) was necessary. Therefore, Premium Car Co's owner introduced a production system, which is similar to Toyota's, and makes use of the ideas about lean manufacturing. One consequence is that employees can now stop the production line in case of problems but they still find it difficult to determine when to stop the line and when to let it continue.

Today, Premium Car Co aims for top quality the first time through. Therefore, every defect is now analysed and traced back to the individual operator. This has been quite a development from the past, when traceability was not possible. Traceability is achieved by means of a simple log book in which employees write down at what car number they started working and at what car number they stopped working. Once Premium Car Co has traced the employee that caused the defect, a conversation is held with him. The quality manager told that:

> *"Such a conversation focuses on how we can improve to prevent the defect from occurring again. Does the employee know something went wrong? Can the process be improved?"*

So, the conversation is not meant to slap the employee on the wrist, but to learn from mistakes.

The mix of cars on the assembly line is also something that still has room for improvement. The Premium Car Co plant can only balance the production mix per day and not, for example, per week. Consequently, one day the plant may produce only 60 cars with automatic gearboxes, while the next day it has to produce 120. This makes a big difference to the employees who work in the engine department, because the cars with automatic gearboxes are very demanding for them. If Premium Car Co could balance the production mix over several days, the plant could produce 90 cars with automatic gearboxes on both days. The managers indicated that some of the competing car manufacturers are more advanced with respect to the production mix. These manufacturers can balance the production mix over several days (or even weeks) and therefore they can realise a nearly constant work load for the employees.

Developing good management control systems is another difficult task for Premium Car Co. The management acknowledges that reward and punishment are essential parts of a management control system, but they find it difficult to apply them. The quality manager told:

> *"We do not want to reward all good behaviour because that would become very costly. We are more in favour of recognition instead of reward. Similarly, we will not punish employees that do not perform well. These employees will just not receive recognition for their work."*

Another problem with management control systems for Premium Car Co is the fact that they work differently on different employees. The managers were agreed that some employees do not want to have any recognition. They just do their work well for their own pride and they do not want to have any recognition from a supervisor or manager. These same feelings also played a role during the transition of the plant from the owner of Premium Car Co to Premium Car Co. Today, it is still not easy for the employees to let go of their feelings for Premium Car Co's owner. Some employees are actually more proud of having been part of the old situation, than of being a Premium Car Co employee now.

7.5.3 Supplier Improvement

The suppliers are an essential party in Premium Car Co's ambitions to improve its products. Currently, approximately 70% of the value of Premium Car Co's cars is bought in from suppliers. Therefore, these suppliers have a significant impact on the quality of the final product. Not surprisingly, Premium Car Co's management has over the last couple of years started focusing more and more on their suppliers.

The owner of Premium Car Co has developed a proprietary quality standard for suppliers. Premium Car Co demands that all its preferred first tier suppliers live up to the requirements of this quality standard. Suppliers need to have certain minimum levels of quality performance in order to receive a certificate of compliance with the standard.

It is a challenge to get suppliers in line with Premium Car Co's commitment to quality. Compliance with quality standards alone is not enough to realise this. Therefore, a cross-functional team has been set up by Premium Car Co to deal with improvements at the suppliers. The quality manager explained that:

> *"This cross-functional team visits suppliers and works together with the suppliers on improvements. The quality systems of the suppliers have to fit with our quality systems. The result of this is strongly increased information exchange between us and our suppliers."*

In order to benefit more from this tight cooperation between Premium Car Co and its suppliers, Premium Car Co would like to reduce the number of suppliers. However, the focus on low costs makes this virtually impossible.

In terms of the costs of components, Premium Car Co's managers find it a challenge not to source for the lowest price but for the lowest life cycle costs. However, Premium Car Co has no clear view on these total life cycle costs yet. All managers were agreed that this is an area in which Premium Car Co needs to develop further. The quality manager told that:

> *"At the moment competitors use smarter sourcing than we do. Some competitors seem to be able to make better use of larger volumes."*

Premium Car Co is of course using its links with its parent company in the relationships with its suppliers. The parent company is a major global player that procures high volumes of components, and it therefore is an interesting (potential) customer for suppliers, which may stimulate these suppliers to keep their prices for Premium Car Co low.

Premium Car Co also makes use of very strict terms and conditions for its contracts with suppliers. These terms and conditions are not just words because

Premium Car Co does enforce them with financial consequences for the suppliers. On the basis of these terms and conditions, Premium Car Co can claim reimbursements for all costs that have resulted from supplier defects and mistakes. Even though these strict contracts are used, Premium Car Co's managers prefer to develop relationships with suppliers on the basis of collaboration instead of punishment. Especially the most important first tier suppliers are treated in a collaborative way. The quality manager claimed that:

> *"The relationship with the suppliers in the industry park around our plant is very good. We cooperate with these suppliers on design and development. The actual contracts between us and the suppliers are more focused on the business level because the suppliers in the industry park are only small plants of a much larger business."*

As argued before, outsourcing the production of more and more parts of a car to suppliers makes it more important to monitor these suppliers. Modular sourcing makes it possible to outsource large parts of a car to suppliers but that also means that more problems with the final product are caused by these suppliers. Premium Car Co's quality manager estimated that approximately 50% of all defects are caused by suppliers. The quality manager argued that:

> *"Problems with suppliers are more serious and harder to solve than problems created by our own employees. Suppliers are moving further away from the plant to countries where wages are low, which makes it very difficult to realise changes up the supply chain towards these remote suppliers."*

On the other hand, Premium Car Co's management understands that the suppliers are also necessary because they sometimes do things better than Premium Car Co could have done it.

It is becoming increasingly important for Premium Car Co that the first tier suppliers manage the second tier suppliers very well. Just a couple of years ago this was not an issue, but outsourcing has resulted in longer supply chains, which are more difficult to manage. Premium Car Co also wants to generate a sense of shared ownership of the final product with its suppliers. The managers feel that first tier suppliers are committed to doing a good job for Premium Car Co but higher tier suppliers are much less committed. Therefore, Premium Car Co's management wants the first tier suppliers to help managing the supply chain. The quality manager told that:

> *"Suppliers in the industry park around the plant have made good progress with respect to the management of second tier suppliers and taking ownership of the final product."*

To facilitate this process, Premium Car Co provides training and advice to its suppliers on how to improve their businesses. Premium Car Co does not only help suppliers to improve processes by means of, for example, Six Sigma, but it also helps suppliers to manage their supply chains.

7.6 The Supplier's Perspective

The interviews with the management of Premium Car Co have shown that the importance and responsibilities of suppliers have increased. Modular sourcing of car components has resulted in a need for more sophisticated suppliers and also in a longer supply chain. For the quality of the final product it is essential that Premium Car Co manages this supply chain to maximum effect. Apart from the view of Premium Car Co's managers on the way they manage the supply chain, it is important to understand the perceptions of their first tier suppliers, which are the other parties in these dyadic relationships. Therefore, this section deals with the views of two suppliers about the changes that have taken place over the years in their relationship with Premium Car Co. These suppliers have been selected by the quality manager of Premium Car Co on the basis of their importance in terms of the components they supply, and on the impact these components have on the final product.

7.6.1 Supplier 1

Supplier 1 belongs to a large global supplier organisation and employs about 100 employees and staff. Supplier 1 is situated in the industry park around the Premium Car Co plant. Supplier 1 started production at this site when Premium

Car Co started assembling there, because the plant is entirely dedicated to Premium Car Co production.

Supplier 1 assembles the following parts for the Premium Car Co cars:

- The instrument panel/cockpit module.
- The centre console, which consists of elements like the handbrake and the arm rest.
- The cooling module, which consists of elements like the radiator and hoses.

The first two modules are delivered directly to the production line of Premium Car Co, while the cooling module is delivered to another supplier. The latter supplier is Premium Car Co's first tier supplier for the cooling module and therefore ships also supplier 1's cooling module to Premium Car Co.

Communication between Premium Car Co and supplier 1 about the supplies that are needed is very clear, according to supplier 1's quality manager. Premium Car Co orders its supplies electronically and supplier 1 manufactures them in the right sequence. Supplier 1 has no real stocks because supplier 1 only manufactures the supplies that are needed and finished supplies are directly sent to Premium Car Co.

Premium Car Co has no alternative supplier for the instrument panel and the centre console. However, for the cooling module Premium Car Co has another supplier. Therefore, supplier 1 is an important supplier to Premium Car Co, which is also the reason why this supplier is situated in the supplier park.

According to the quality manager, supplier 1 can currently make one million variations of the Premium Car Co instrument panel. Although the experiences inside the Premium Car Co plant indicated that product variety is enormous, this still seems to be inconceivably high. It was not clear whether supplier 1 had ever started counting all possible variants. In any way, there are probably so many variants that the actual number is not very relevant.

Supplier 1 uses ISO/TS 16949 (see ISO, 2002) and has won quality awards on a corporate level. Supplier 1 does not use quality award models like the EFQM model (see for example Van der Wiele et al., 1996; Ritchie and Dale, 2000) at the Premium Car Co site.

The quality manager of supplier 1 is in principle responsible for managing second tier suppliers, but in practice that depends on how the selection process of the supplier has taken place. This is the result of Premium Car Co's direct involvement in the selection of some of its second tier suppliers. Supplier 1 can have three different forms of responsibility over its suppliers, depending on the arrangements made:

1. Premium Car Co selects and buys. In this case second tier suppliers are selected by Premium Car Co and it also pays these suppliers for the parts. Supplier 1 builds these parts into the modules for Premium Car Co but it is not responsible for the second tier suppliers because Premium Car Co is responsible for all problems with these suppliers. This way of sourcing means that Premium Car Co sometimes selects a second tier supplier for supplier 1 that supplier 1 would never buy from if it were to choose. Sometimes supplier 1 has to use parts from a second tier supplier, while the same parts are manufactured by another plant of the organisation to which supplier 1 belongs.

2. Premium Car Co selects and supplier 1 buys. In this case Premium Car Co selects the second tier suppliers for supplier 1, but supplier 1 buys the parts from these suppliers. This way of sourcing can lead to confusion about the responsibilities that Premium Car Co and supplier 1 have for these suppliers.

3. Supplier 1 selects and buys. In this case supplier 1 buys the parts from self-selected suppliers. This means that supplier 1 is completely responsible for these suppliers.

With respect to quality issues, supplier 1's quality manager stays in close contact with Premium Car Co's quality manager. Apart from these ongoing interactions, there are also more formal ways of discussing quality issues. Every two weeks a quality review meeting is organised with Premium Car Co. The agenda for these meetings is determined by supplier 1 but Premium Car Co can of course put things on the agenda too. Recently there was an issue with the ventilation shafts of the cars because these shafts made a squeaking noise. The quality manager of supplier 1 told:

> *"This problem was discussed during one of the quality review meetings. However, because of the frequent contacts between Premium Car Co and us, the problem was already known and we had already developed a solution."*

Besides the quality review meetings there are also plant quality review meetings at Premium Car Co. Suppliers are only invited to these meetings if it is necessary. Supplier 1 also has its own quality meetings during which issues related to for example strategy, problems and warranty are discussed.

The cooperation between Premium Car Co and supplier 1 is not just limited to meetings and personal interactions. Premium Car Co also reviews supplier 1's product lines to help improve them. Moreover, Premium Car Co gives training to employees of its suppliers (e.g. Six Sigma training).

Another sign of the close cooperation between Premium Car Co and supplier 1 is the fact that employees of supplier 1 are working inside Premium Car Co's plant. These employees work for example in the interior trim department and the climate department of Premium Car Co, but they are paid by supplier 1. The quality manager explained:

> *"Under normal circumstances these employees just work together with the Premium Car Co employees. However, if there is a problem with our supplies, then our employees are responsible for taking action."*

The quality manager feels that Premium Car Co has a strong focus on sourcing for the lowest costs. He told:

> *"Once the supplier contract has been signed, the supplier then has to improve for the same low price. Even though Premium Car Co manufactures premium cars, it will not allow suppliers to charge high prices."*

Supplier 1 feels that it is very difficult to persuade Premium Car Co to make changes to the car, because they will cost money for Premium Car Co. At the time of the interview, there was an issue with the clips that hold the cover around the steering column. These clips were too weak and could therefore break. Premium

Car Co only started looking into this issue when it had resulted in warranty claims, which also cost Premium Car Co money.

The fact that supplier 1 is situated in the supplier park around Premium Car Co has the advantage of short communication lines with the people of Premium Car Co, but it has also disadvantages. The major disadvantage, according to supplier 1's quality manager, is that Premium Car Co is very likely to blame the suppliers in the industry park when something goes wrong in the production process. The quality manager told:

> *"Basically these suppliers have to prove that it is not their fault that something went wrong in Premium Car Co's processes but that Premium Car Co itself is to blame."*

Supplier 1 believes that supplier selection by Premium Car Co is mostly based on previous performance of a supplier. Suppliers are often already involved in the design phase of a new car model and once a supplier is involved in the design phase its chances of winning the eventual contract are very large, according to the quality manager. Therefore, it is very important to perform well for the current car model in order to win future contracts.

This performance is measured by Premium Car Co by means of all kinds of performance indicators. These indicators are available in an internet based system, which informs the suppliers about their performance. This system is updated once per month and contains the following indicators:

- Defects (PPM)
- Delivery performance
- Quality certification and performance
- Warranty spikes
- Stop shipments
- Product audit (tests of cars from a consumer perspective)

These measurements are believed to be important to achieve high quality and survive on the long run. Supplier 1 understands very well that quality is especially important when a supplier manufactures parts for a brand like Premium Car Co.

For supplier 1, Premium Car Co is just a brand of Premium Car Co's owner, except for the quality demands which are higher.

If a supplier does not perform well and causes, for example, a stoppage of Premium Car Co's production line, it will have to pay the costs. This fact does not bother the quality manager of supplier 1 at all. He argued:

> *"That is just part of the normal way of doing business in the automotive sector. The suppliers agree to the contract, so they have to pay the fine if they do not live up to the contract."*

As far as supplier 1 is concerned, these punishments do not have any effect on the day-to-day cooperation between supplier 1 and Premium Car Co. It is no problem for supplier 1 to closely cooperate with Premium Car Co and at the same time receive a bill for a problem that has been caused. These things are separated for supplier 1's quality manager.

Supplier 1 is aware that future performance will be determined to a large extent by the performance of second tier suppliers. The quality manager summarises:

> *"Many automotive suppliers have to manufacture larger systems and modules for the car manufacturers. As a consequence, their supply chains have become longer and more responsibility is shifting to the smaller second and third tier suppliers. Therefore, more attention needs to be paid to managing these second and third tier suppliers."*

7.6.2 Supplier 2

Supplier 2 is a supplier of a diverse range of automotive components. It is a major supplier world-wide to many plants of Premium Car Co's owner. Its strengths are in interior components such as seats. Supplier 2 has always been an independent company and is known as a very good lean manufacturer. It has reached its current size predominantly as a result of organic growth. The production site of supplier 2 that supplies Premium Car Co is located on the supplier park around Premium Car Co.

Supplier 2 assembles the following parts for the Premium Car Co cars:

- The door panels.
- The overhead system, which consists of elements like the headliner.
- The plastic covers on the B and D pillars of the car.
- The hat tray.

Supplier 2 delivers its supplies in sequence and Just-In-Time. Therefore, the employees at supplier 2 need to manufacture exactly the right variant of product at the right moment. To make sure that this happens, supplier 2 now has far more poka yoke systems than it used to have (e.g. lights that blink and videos).

In the past supplier 2 manufactured the seats for the cars that Premium Car Co's owner used to assemble at the plant. Comparing the old situation with the current situation, the quality manager of supplier 2 indicated that a lot has changed. Especially the manufacturing complexity has increased over the years. The seats that supplier 2 assembled for the old cars came in very few varieties, while the current car parts that supplier 2 assembles for Premium Car Co come in many varieties. The quality engineer told that especially the number of different colours is enormous.

Once the production of the new SUV starts at the Premium Car Co plant, supplier 2 will again supply the seats and the overhead system (i.e. headliner etc.). So, basically supplier 2 will switch back again to what it did years ago. This seems to be quite inefficient for Premium Car Co and supplier 2, in terms of building up experience. Given that the plant of supplier 2 is dedicated to production for Premium Car Co, they have ceased assembling seats when Premium Car Co took over the plant from its owner. Similarly, the current supplier of seats has built up experience during the assembly of the Premium Car Co cars, but will not be allowed to use that experience for the seats of the new SUV. However, supplier 2's quality manager argues that this is less inefficient than it seems:

> *"Because of the major changes between old car models and new ones, the existing equipment is quite often useless. So, the supplier has to invest in new equipment anyway.*

Therefore, it does not really make a difference if the car manufacturer switches to another supplier at that moment."

As an example, the quality manager told that the seats in the old cars of Premium Car Co's owner were very standard (there were only two variants), while the new SUV will have many different types of seats with all kinds of electronics in them). However, when comparing the SUV with the current Premium Car Co cars, the changes are much less dramatic, since Premium Car Co cars also have electronics in them. When asked about the effects on investments in intangible assets like employee training and the existing knowledge base, the quality manager told he does not worry much about that. He argued that supplier 2 still has employees working in its plant that already worked there when they manufactured the seats for the old cars of Premium Car Co's owner.

In day-to-day operations, supplier 2 works closely together with Premium Car Co. Supplier 2 employs people who work inside Premium Car Co's plant. These employees work together with Premium Car Co employees. Supplier 2 also has adopted Premium Car Co systems (e.g. problem solving systems), which makes it easy to communicate. There are frequent meetings between supplier 2 and Premium Car Co on development issues and problems. The quality engineer of supplier 2 told that:

"Both companies are data-driven, which means that tracking systems are in place and decisions are based on facts. Both companies also have an engineering mentality and therefore they can cooperate very well."

The fact that supplier 2 has been a supplier for the Premium Car Co plant for quite some time, is seen as a reward for its good performance. Once Premium Car Co starts the production of the SUV, supplier 2 will have supplied the same plant for three consecutive car models. Already during the production of the first of these three cars, supplier 2 had formally become a preferred supplier to the wider organisation of Premium Car Co's owner. The quality manager and quality engineer argued that, in general, a supplier's chance of success to win the contract for a next car model depends on its performance with the current model.

In order for supplier 2 to become preferred supplier, it had to comply with the demands of the proprietary quality standard of Premium Car Co's owner. Supplier 2 understands that this is a necessity for suppliers, but it also believes that suppliers should be flexible and have performance measures themselves. Contrary to the impressions that Premium Car Co's managers gave, supplier 2 does not perceive the demands of the quality standard as very strict. The quality manager of supplier 2 explained:

> *"We have our own performance targets, which are much higher than what Premium Car Co demands. If suppliers raise the bar above the minimum demands, their recognition will not immediately be in danger if they happen to fall below their own standards. Apart from that, there is of course the pride of being the best supplier."*

The quality manager of supplier 2 is aware that living up to the demands of a quality standard, or even exceeding them, will not be enough to assure good quality components in an environment of high product variety. He told:

> *"When products and processes become more complex, they will lead to more issues and problems. Therefore, it is very important to pay attention to the details of a car and its parts before the car is launched."*

Premium Car Co nowadays cooperates a lot with its suppliers on the development of new car models. According to the quality engineer of supplier 2, a lot of effort is nowadays put into the design and the quality of the design, for example by making use of Design Failure Modes and Effects Analysis (Design FMEA, see Stamatis, 2003).

Although a large part of the production of new car models will be outsourced, Premium Car Co is still strongly involved in the design of the car components. By doing so, Premium Car Co tries to stay abreast of the necessary knowledge, in order not to be completely dependent on its suppliers. On the other hand, Premium Car Co also has a lot of expertise to offer to its suppliers. The quality engineer explained:

> *"The knowledge transfer during the design phase is not only from suppliers to Premium Car Co, but also in the other direction. Premium Car Co really helps the suppliers and guides them through the design phase to eliminate potential defects in an early stage."*

During the design phase, Premium Car Co will sometimes prescribe which second tier suppliers need to be used for a component, but supplier 2 has no problems with that because this is very common in the automotive industry. The same thing goes for the strict contracts that are enforced when suppliers deliver faulty parts to Premium Car Co. If a part is rejected by Premium Car Co, it will charge the supplier for the costs of the part and for administrative and other costs involved. The quality manager explained:

> *"This is just the normal practice. Suppliers sign the contracts and agree to the terms and conditions, so they know that this can happen. After all, this is not just the practice between car manufacturers and their first tier suppliers, but also between first tier and second tier suppliers. The company that made the fault will receive the bill."*

Even though the bill will eventually be paid by a second or third tier supplier, Premium Car Co will first put the blame on the first tier supplier that delivered the faulty component. To prevent this from happening, supplier 2 has recently implemented a new electronic quality system. This system provides data on all issues from the customer (i.e. Premium Car Co) and also information about the performance of suppliers. The major benefit of this system is, according to the quality manager, the ability to monitor its suppliers. By monitoring its suppliers, supplier 2 can proactively look for problems that could develop further down the supply chain (i.e. at Premium Car Co's assembly line, or at the final customer). Supplier 2 made the development of this system a top priority in recent years because the use of modules and systems forced supplier 2 to manage its suppliers better. This system was an initiative of supplier 2 and was not demanded by Premium Car Co.

Another means for improvement that supplier 2 has been using already for eight years, is the Six Sigma improvement method. In all departments employees have been trained in Six Sigma. Supplier 2 is prepared to invest in Six Sigma because it is seen as a very important tool. The quality engineer told that Premium Car Co also uses Six Sigma, which offers opportunities to cooperate on improvement projects. Supplier 2 and Premium Car Co run cross-functional and cross-organisational teams that work on Six Sigma projects. However, during the interview with the quality manager of Premium Car Co, he did not present Six Sigma as a very important improvement method.

The quality manager of supplier 2 is aware that quality systems and tools will not improve quality, unless the people who have to work with them are willing and able to achieve the organisation's goals. He told:

> *"The mentality of the employees is a key factor. Employees need to understand the business objectives. They should be willing to work on continuous improvement and develop themselves further. The tools and machines are not everything because in the end it is the employees who can make a difference."*

Therefore, it is important that employees are motivated by the organisation they work for. Both the quality manager and the quality engineer are convinced that supplier 2 succeeds very well in this. Consequently, the employees are stimulated to achieve challenging goals. The quality manager summarised:

> *"The people should want to achieve and then the data speak for themselves."*

7.7 Discussion of Findings

It is clear that Premium Car Co is an organisation that is struggling with product variety issues. Not only does it offer its customers an enormous number of options, but it also adapts the basic car body to the region where the car will be sold. As a consequence of the large number of variants, some variants are rarely sold. The large number of variants makes the cars very complex, which has consequences for the assembly process. For the future, Premium Car Co wants to reduce the complexity of the cars.

At the time of the interviews and the factory tours, the management of Premium Car Co still hoped that shortening product life cycles would not affect the premium car segment as much as it does the non-premium segment. However, at the time of writing this chapter, there are clear signals that the planned life cycle of the car model is too long. For example, sales are declining rapidly, while the car model was planned to last until 2009 without modifications. This may necessitate

Premium Car Co to bring the introduction of a predecessor forward and thereby shorten the life cycle of the current model.

So, the two trends of increasing product variety and shortening product life cycles are clearly influencing this organisation. At the same time, Premium Car Co cannot risk eroding the quality of its cars. Assembling top quality cars is seen as a prerequisite by the management for being eligible for the ‘premium’ label. The Premium Car Co plant appears to be able to deliver top quality cars, since its ranking in the industry leading J.D. Power Initial Quality rankings is very high (see www.jdpower.com). This also means that Premium Car Co is doing well with respect to the more emotional quality aspects, which have become much more important over time. The current high quality performance of Premium Car Co has resulted in a contract to manufacture a new SUV model for Premium Car Co’s owner.

This is all in sharp contrast with the past, when the current Premium Car Co plant was performing poorly in terms of quality, even to low-cost non-premium standards. On the basis of the case study, we can conclude that Premium Car Co achieves its high quality levels predominantly by means of end-of-line inspections and the fire-fighting and innovative skills of the employees. The management takes pride in these fire-fighting and innovative skills. However, it is questionable if this way of working is the most efficient way of producing high quality products. Few checks take place during the production process, when it is still relatively easy and cheap to fix problems.

So, the management of Premium Car Co seems to focus much more on the products than on the processes. This also goes for planning processes, which the management of Premium Car Co rates as ‘somewhat poor’. The lack of process focus may also be due to the unavailability of many cost data. If cost data are not available, it is not clear what the cost savings would be if the focus would be more on the process instead of on the product.

During the time of the interviews, Premium Car Co’s managers did in fact start to look into cost data because their owner wants to start treating the Premium Car Co plant as a profit centre. As outlined in this chapter, this has already led to discussions about the cost-benefit ratio of many customer options. During these discussions, the assembly costs of the options also play a role, apart from the development costs.

Another reason why process data are becoming more important at Premium Car Co, is the shift of production to suppliers. Suppliers determine increasingly the quality of the end product, and at the same time supply chains are becoming longer. This means that Premium Car Co has to focus on the processes that take place at these suppliers, as well as on the way first tier suppliers manage second and third tier suppliers.

So, the Premium Car Co plant has developed from a poor quality plant, via a high quality plant that depends on (inefficient) quality inspections, to a plant that is starting to focus on data-driven decision making and quality embedded in the processes (both at the Premium Car Co plant and at the suppliers).

The mentioned developments are summarised in table 7.3, where each row indicates one development from past, via present, to future. Obviously the right hand column is based on the intentions of the management, and it is not possible at this stage to predict whether these intentions will materialise. Premium Car Co has made enormous quality gains over the last decade. Ten years ago, it was the worst of three plants that produced the same car model, while now it is highly appreciated within the organisation of Premium Car Co's owner and it ranks high in the global J.D. Power automotive quality rankings. The management of Premium Car Co is confident that it can continue this success in the future with the production of the new SUV.

Table 7.3: Developments over time at Premium Car Co

Past	Present	Future
▪ Few product variants	▪ Extreme number of product variants	▪ Many product variants, as long as they are economical
▪ Long product life cycles	▪ Decreased product life cycles	▪ Decreased product life cycles
▪ Simple products	▪ Very complex products	▪ Reduced product complexity
▪ Focus on technical quality issues	▪ Growing importance of emotional quality issues	▪ Growing importance of emotional quality issues
▪ Poor product focus	▪ Strong product focus	▪ Strong product focus
▪ Poor process focus	▪ Poor process focus	▪ Strong process focus
▪ Production in-house	▪ Production to a large extent outsourced	▪ Production to a large extent outsourced
▪ Few data for decision making	▪ Few data for decision making	▪ Data-driven decision making
▪ Poor manufacturability	▪ Poor manufacturability	▪ Good manufacturability
▪ Radical changes	▪ Radical changes	▪ Gradual improvements
▪ Many end-of-line quality inspections	▪ Many end-of-line quality inspections	▪ Few end-of-line quality inspections
▪ Few quality checks embedded in assembly process	▪ Few quality checks embedded in assembly process	▪ Many quality checks embedded in assembly process
➔ Poor quality cars	➔ High quality cars	➔ High quality cars?

The way Premium Car Co manages the quality of its products and processes has changed over the years, with the following being the major changes identified:

- In the past, suppliers would only produce individual components, while assembly of these components used to take place at the Premium Car Co plant. Thereafter, Premium Car Co started outsourcing the production and assembly of many components to suppliers. By doing so, Premium Car Co shifted the responsibility for the complexity of the assembly process to these suppliers. Premium Car Co would manage these suppliers in a very strict way by claiming that all quality problems are the responsibility of the suppliers and they had to solve them alone. More recently, Premium Car Co's management has learnt that many problems are due to the design of the cars, and that it is beneficial to both Premium Car Co and its suppliers if they cooperate before and during the assembly process. A related issue is the extent to which cars are designed for assembly. In the past cars would be standardised and simple, however, the current car model of Premium Car Co is highly complex and designed to appeal to customers. For the future, Premium Car Co will still try to design cars that appeal to customers, while at the same time improving their manufacturability.

- In the past, decision making would be ad-hoc and based on opinions and impressions. Premium Car Co has learnt that this may sometimes lead to inadequate decisions. Therefore, it has gradually shifted towards decision making on the basis of data, but it appeared that the available data at Premium Car Co is very limited. A future objective is to collect and use more objective data for decision making purposes.

- Quality improvement at Premium Car Co is currently quite radical and irregular. Engineers will come up with ideas for improvement, which are then implemented. However, afterwards there is no follow up and the employees are not really involved. The management believes that it is necessary to change this and involve the employees in improvement activities as well. This should allow the organisation to have a more gradual but continuous improvement approach.

- Currently, the quality of the cars is achieved by many and thorough end-of-line inspections. Since this is not the most cost-efficient way to assure the quality of the cars, Premium Car Co would like to reduce its reliance on end-of-line inspections and replace them, to an extent, with in-line checks.

- Premium Car Co is an organisation with a strong engineering heritage. Traditionally, the engineers were the people who determined if the quality of a car was sufficient or not. More recently, the management has tried to change the engineering culture by emphasising that the customer is the one who determines if the quality is sufficient or not.

- The use of robots has also changed at Premium Car Co. Over the years, the management has learnt that robots are handy for production and inspection when processes are predictable and constant. The enormous number of product variants that Premium Car Co currently assembles, has reduced the usefulness of robots. Therefore, the importance of the employees for achieving high quality products has again increased. The management believes this trend will continue in the future, and employees will become responsible for driving the processes.

The mentioned developments in the quality management systems are summarised in table 7.4, where each row indicates one development from past, via present, to future.

Table 7.4: Developments in quality management systems at Premium Car Co

Past	Present	Future
▪ Assembly in-house	▪ Assembly to a large extent outsourced and suppliers managed with stick	▪ Cooperation with suppliers before and during assembly
▪ Standardised cars	▪ Highly diversified cars	▪ Design for manufacturing
▪ Ad-hoc decision making	▪ Decision making on the basis of limited data	▪ Data-driven decision making
▪ Radical improvement approach	▪ Radical improvement approach	▪ Gradual improvement approach
▪ Quality assurance by means of end-of-line inspections	▪ Quality assurance by means of end-of-line inspections	▪ Reduced reliance on inspections, while more checks embedded in assembly process
▪ Engineers determine quality of the cars	▪ Customers determine quality of the cars	▪ Customers determine quality of the cars
▪ Robots necessary for production and inspection	▪ Increased importance of employees for high quality	▪ Employees drive processes

7.8 Summary

This chapter has presented and discussed the case of Premium Car Co. The views of the management with respect to the two trends of increasing product variety and shortening product life cycles have been presented. The consequences of these for the management and improvement of quality have been discussed, both from the point of view of the management, as well as from the point of view of two major suppliers. These views have been complemented by the impressions of the researchers during factory tours.

Especially product variety is enormous at Premium Car Co, although comparisons with the past were difficult because of the plant’s history of non-premium cars.

However, the management's experiences with previous cars from the Premium Car Co brand helped to distinguish relevant developments. Also the planning for the new car model that will be produced by Premium Car Co gave insights into the direction in which Premium Car Co will develop in the near future.

The comparative analysis between Premium Car Co and the other two case companies is presented in chapter 8. That chapter also interprets the developments at the case companies from the perspective of Simons' four levers of control model.

8 Cases: A Comparative Analysis

8.1 Introduction

In this chapter the findings from the three case companies are analysed and compared. The chapter starts with a comparative analyses of quality management, product variety and product life cycles at the case companies. The key developments that have taken place at each of the case companies are then presented. Thereafter, the research model of this study is applied to the three cases, which categorises the developments in quality management in terms of Simons' control model. The chapter ends with some tentative conclusions on the basis of the case studies, and distinguishes some issues that require further research.

8.2 Quality Management, Variety and Life Cycles

In this section the importance of quality for each of the three case companies is compared, in order to understand what differences there are between the cases with respect to the need to maintain and improve quality. In addition, the relevance and impact of the two studied trends of product variety and product life cycles are reviewed, based on the hypotheses presented in table 4.2.

8.2.1 Quality Management

The need for the three case companies to offer high quality products is presented below for each of the three core building blocks that have been used throughout this thesis (i.e. customer focus, reduction of variation in organisational processes, and continuous improvement).

Customer Focus

The three case companies sell their products to very diverse customers. Small Car Co has many end customers who drive its cars, however, in terms of Small Car Co's business model, only the two car manufacturers that sell the cars are Small Car Co's direct customers. Small Car Co has no brand responsibility for the two car models because it operates as an independent contract manufacturer that gets paid for every car it assembles. This means that end customer focus is only of indirect importance to Small Car Co, because a poor customer focus will lead to fewer cars produced and therefore to lower profits.

Premium Car Co has many end customers as well, and these are the direct customers of Premium Car Co because the plant is held responsible for the car model it assembles. The Premium Car Co plant is the only production location of the entire Premium Car Co organisation that assembles the specific car model, and as such it should deal with the end customers. These end customers are very demanding, because they expect top quality since they are buying a premium product. The most difficult customer demands for Premium Car Co are the ones that are related to the more emotional aspects of the car (e.g. the sound of a closing door).

Heavy Truck Co has fewer end customers because heavy trucks are sold to corporate customers, who typically buy multiple trucks. The demands of these customers are to a large extent driven by rational cost-benefit analyses. The most important quality demand is that the trucks do what they are expected to do. Operational performance over time is the most important aspect of Heavy Truck Co's customer focus. It is essential that trucks do not break down because that can lead to significant financial and reputation damage.

Reduction of Variation in Organisational Processes

Given the importance of operational performance for Heavy Truck Co's customers, reduction of process variation is necessary for Heavy Truck Co, in order to assemble trucks of constant quality. The durability of all truck components should enable the trucks to run for 1.6 million kilometres without problems. In combination with the variety of trucks on the assembly line, this means that Heavy Truck Co should have its processes under control.

Small Car Co also has a strong incentive to maintain tight control over its processes, because it receives 12% to 14% of the value of each car that it assembles. So, reduction of variation in organisational processes is critical to make profit on the cars. Given that many processes have been outsourced to suppliers, it is essential that Small Car Co has a means to assure that processes at the suppliers are under control as well. The need for this was recently emphasised in the press, when Ford plants were idled for two days as a result of a defect part (Sherefkin and Wilson, 2006).

Premium Car Co has the least incentive to reduce variation in organisational processes. The organisation is able to sell its cars for a relatively high price because customers are willing to pay a premium for the brand experience that comes with its cars. This high price reduces the need to have efficient process control, which is in line with the practices at the Premium Car Co plant. Currently, a heavy reliance on end-of-line inspections is meant to guarantee that only top quality cars are delivered to customers, however, the costs of this approach are high.

Continuous Improvement

Continuous improvement is important for Small Car Co in order to maintain its profit margin for the future. The organisation is under constant costs pressure, resulting from increasing commodity prices, increasing labour costs, and stricter environmental and safety demands. These costs developments would erode Small Car Co's profit margin if it would not continuously find and implement improvements that offset the costs developments. In addition, the short life cycles of the car models that Small Car Co assembles, necessitates the organisation to improve rapidly during the start-up phase of production, which is typically the least efficient production phase. When life cycles were longer, Small Car Co could compensate the inefficient start-up phase with efficient production during the remainder of the life cycle. Today, the life cycles are too short to compensate initial losses during the later stages of the life cycle.

Heavy Truck Co needs to continuously improve its processes as well. The margins in the transportation industry, which is the most important market segment for Heavy Truck Co, have decreased significantly over the years. Transportation companies are therefore constantly looking for costs reductions. A major costs component for transportation companies are the operating costs of the trucks. If Heavy Truck Co can improve its processes and thereby reduce the price of its trucks, this will appeal to transportation companies. The current emphasis on Six Sigma improvement projects at Heavy Truck Co underscores the importance of continuous process improvements.

Given that Premium Car Co does not have a strong focus on process control, continuous improvement of the processes is also less of a priority. Again, the fact that customers are willing to pay a price premium for its cars allows Premium Car Co to rely on end-of-line inspections instead of quality embedded in the organisational processes. In the near future, the car model that the Premium Car Co plant assembles will be treated as a profit centre, and therefore the organisation may be forced to continuously improve its performance.

8.2.2 Product Variety

The relevance of increasing product variety is discussed below for each of the three case companies. This discussion is structured along three scales (i.e. visible vs. invisible, functional vs. emotional, and potential vs. actual) that were found to be relevant on the basis of the case study examinations. Moreover, the visible vs. invisible scale is virtually the same as a scale used by Fisher et al. (1999).

Visible vs. Invisible

All three case companies make a distinction between vehicle components that are visible to the customer and components that are invisible to the customer. However, the way they deal with these two groups of components is different for the three cases. Small Car Co has a clear strategy of standardising as much as possible of the invisible components, while differentiating the visible components. This leads to car models that look completely different from each other, although they share many components. By means of this strategy, Small Car Co has managed to limit the variety on its assembly line.

Premium Car Co has tried a similar strategy by cooperating with another brand of the wider organisation to which it belongs. However, the desire to maintain its own identity resulted in only four components that are shared between the two car models (see section 7.5.1). The fact that components are not visible to customers does not imply that customers will not notice them (e.g. chassis, suspension, engine construction etc.). Concentrating only on the components that customers do not notice in any way, will mean that there is very little left to commonise (e.g. batteries, cables, hoses etc.).

Heavy Truck Co shares components between its truck models as well, and because of the more rational buying behaviour of its customers it is even not a problem to share some of the visible components. Heavy Truck Co has been sharing the invisible powertrain components between the two truck models for many years. However, more recently it gave the two truck models identical headlights, which clearly are visible components.

Functional vs. Emotional

The extent to which the three case companies make use of the distinction between visible and invisible components is closely related to the importance of this distinction between functional and emotional components. Some vehicle components are purely functional and the driver may not even be aware of their presence (e.g. gears, drive shafts, hoses, cables etc.), while others are more emotional (e.g. engine, suspension, chassis, brakes, sound system, airco etc.). The functional components can be commonised between different vehicles, while the emotional components determine the image of the vehicle. Moreover, the image of the vehicle could improve when more emotional components are available for customers to choose from.

Heavy Truck Co is mostly concerned with the functional components because these are the components that truck buyers assess when deciding for a certain truck. Therefore, it is possible for Heavy Truck Co to commonise parts between truck models without hurting its image in the market place. On the other hand, it is not much use to add emotional components because they would increase the price of the trucks without improving their abilities to accomplish the tasks they were designed for.

Premium Car Co is at the opposite end of the scale. The price premium that customers are willing to pay is based on the image of the car in the market place. Therefore, Premium Car Co believes it should be careful when commonising parts between car models. Moreover, the addition of emotional components to the options list is believed to maintain, or even increase the image of the car. These two beliefs explain to a large extent the enormous number of product variants that Premium Car Co offers to its customers.

Small Car Co is somewhere between Premium Car Co and Heavy Truck Co when it comes to technical vs. emotional components. The market for small cars is very competitive and customers in this segment are typically not willing to pay a price premium. Therefore, Small Car Co has a more limited options list than Premium Car Co, although it tries to make extra money on its cars by offering some emotional components. On the other hand, Small Car Co can more easily save costs by sharing components between cars then Premium Car Co can.

Potential vs. Actual

The final dimension of product variety is potential vs. actual, which makes a distinction between the number of product variants that are technically possible, and the number that is actually produced.

Heavy Truck Co and Small Car Co are at the same end of this dimension, while Premium Car Co is at the opposing end. Heavy Truck Co's potential product variety has not increased significantly over the last decade, while the actual product variety on its assembly line has. This is due to the fact that today more customers than in the past are opting for a truck that closely matches their needs. As a consequence, potential and actual variety are now more or less equal to each other at Heavy Truck Co.

At Small Car Co, actual variety is approximately equal to potential variety as well. Customers are of course different in the extent to which they choose options for their cars, but the offered options are all regularly sold.

Conversely, Premium Car Co offers an enormous number of product variants to its customers, however, some of these have never been chosen by a customer. So, the potential product variety at Premium Car Co is higher than the actual product variety.

8.2.3 Product Life Cycles

The relevance of shortening product life cycles is discussed below for each of the three case companies. This discussion is structured along three scales (i.e. customer demand vs. regulation, core vs. peripheral, and product vs. process) that were found to be relevant on the basis of the case study examinations.

Customer Demand vs. Regulation

Life cycles of vehicles can become shorter for various reasons, of which the major ones identified are customer demand (i.e. declining sales because vehicle becomes outdated) and regulations (i.e. regulatory demands force manufacturers to develop new vehicles).

The life cycles of Small Car Co's car models are clearly influenced by the effects of changing customer demand. While previous car models had a life cycle of seven to ten years, the current two car models are expected to last only five to six years.

Heavy Truck Co's trucks are not much influenced by changing customer demand since this has only increased over the last couple of years. However, the life cycles of the trucks have become shorter than in the past, which is mostly due to intensified government regulations. Norms for the emission of nitrous oxides and soot particles are becoming ever stricter, which requires Heavy Truck Co to introduce new or updated powertrains on a regular basis. Similarly, tougher safety demands require Heavy Truck Co to regularly update the design of the trucks.

Premium Car Co's managers claimed during the interviews that their cars would not be influenced strongly by customer demand or regulations. However, since the period in which the interviews took place, there have been signals in the press that the life cycle is under pressure from changing customer demand.

Core vs. Peripheral

The effects of changing customer demands and regulation on the manufacturers are dependent on the extent to which modifications are required. If diminishing customer demand can be countered by peripheral changes like rejuvenating the design of the vehicle, then the impact is much smaller than when the core product needs to be replaced.

Of the three case companies, only Heavy Truck Co is pursuing a strategy of product upgrades that includes minor changes, as well as major replacements. However, Heavy Truck Co is least influenced by changes in customer demand. Still, its management believes that even regulatory changes do not always require major changes. When emission demands are tightened, Heavy Truck Co could develop a new engine from scratch, or look for modifications to the existing powertrain.

Both Small Car Co and Premium Car Co are thinking in major model changeovers and do not plan any minor changes to their car models.

Product vs. Process

The relevance of shortening product life cycles is dependent on the extent to which processes are dedicated to a single car model. If a production process has been developed for one specific car model, the life span of the process is completely dependent on the life cycle of the car model. However, if a production process is flexible and can be utilised for multiple car models, the production process can outlive the individual car models.

In the distant past, Heavy Truck Co was the only case company that manufactured two truck models on the same production line. However, Small Car Co started manufacturing two car models on one production line, before it started producing the current two models (which also share one production line). Premium Car Co is still manufacturing one car model on its production line, however, it will adapt its production line to accommodate the new SUV model that it will manufacture in the near future. The switch to multiple car models per assembly line appears to be a general development in the automotive industry (The Economist, 2006).

The above discussion is summarised in table 8.1. This table shows that the management and improvement of quality is clearly still a top priority for all three case companies, although the main drivers for working on quality differ between the cases.

The findings about the effects of increasing product variety and shortening product life cycles for each case company are in line with the hypotheses presented in table 4.2. The effects of increasing product variety are the strongest for Premium Car Co and the weakest for Heavy Truck Co, because Premium Car Co has expanded product variety significantly while Heavy Truck Co has seen only a modest increase. The effects of shortening product life cycles are the strongest for Small Car Co and the weakest for Heavy Truck Co, because Small Car Co has had to deal with a significant reduction of the life cycles of its car models while the reduction at Heavy Truck Co has been relatively moderate.

Table 8.1: Importance of quality and influence of product variety and life cycles

	Case company 1 Heavy Truck Co	Case company 2 Small Car Co	Case company 3 Premium Car Co
Importance of quality	*High:* Corporate customers demand that the trucks do their job without breaking down.	*High:* Essential for making a profit, and therefore for the continuity of the organisation.	*High:* Customers expect top quality from a premium car. Especially with respect to the more emotional aspects of the car.
Influence of product variety	*Low:* Product variety is caused by functionality demands, and has as such not increased much. However, actual product variety has increased because more customers are buying trucks that closely match their needs.	*Medium:* Commonising components between car models has had a moderating effect on the increase in product variety.	*High:* Component variety strongly related to emotions instead of functionality, which has proliferated product variety.
Influence of product life cycles	*Low:* Life cycles somewhat shorter as a result of regulatory changes. However, many peripheral changes possible.	*High:* Life cycles significantly shorter as a result of changes in customer demand.	*Medium:* Life cycles shorter as a result of changes in customer demand. Tries to redevelop production process to accommodate multiple car models.

8.3 Examination of Key Developments

This part pulls together the major developments that have taken place at each of the case companies. These developments have already been presented and discussed in the findings section of each of the case chapters. This section will outline the differences and commonalities between the case companies.

8.3.1 Heavy Truck Co

The major developments at Heavy Truck Co are summarised in table 8.2. This table shows that outsourcing has been a major development for Heavy Truck Co. For the future, Heavy Truck Co focuses on design for recycling and improving the quality of the look and feel of the trucks.

Table 8.2: Developments over time at Heavy Truck Co

Past	Present	Future
▪ Production and development in-house	▪ Production to a large extent outsourced	▪ Production and development to a large extent outsourced
▪ Rational product focus	▪ Rational focus and attention to the comfort of the driver/user	▪ Trucks will have the same high-quality finish as passenger cars
▪ Design for functionality	▪ Design for quality	▪ Design for recycling

8.3.2 Small Car Co

The major developments at Small Car Co are summarised in table 8.3. As for Heavy Truck Co, outsourcing and managing the supply chain have been a major development for Small Car Co. Other major developments have been the emphasis on preventing quality problems, the increasing complexity of both cars and processes, and the stronger involvement of employees in assuring the quality of the cars.

Table 8.3: Developments over time at Small Car Co

Past	Present	Future
▪ Focus on curing quality problems	▪ Focus on preventing quality problems at first tier suppliers	▪ First tier suppliers become responsible for preventing problems at higher tier suppliers
▪ Production in-house	▪ Production to a large extent outsourced	▪ More outsourcing, while suppliers move to more distant countries
▪ Simple cars	▪ Complex cars	▪ Even more complex cars
▪ Automation is key to high quality products	▪ Employee is key to proper use of equipment and high quality products	▪ Employee is key to proper use of equipment and high quality products
▪ Shop floor employees build up task routines	▪ Product and task variety forestall routines	▪ Product and task variety forestall routines
▪ Different car models with different components	▪ Differentiate visible parts between car models, while standardising invisible parts	▪ Differentiate visible parts between car models, while standardising invisible parts
▪ Quality department is responsible for managing quality	▪ Quality is the responsibility of all departments	▪ Quality is the responsibility of all departments
▪ Managing manufacturing operations	▪ Managing suppliers	▪ Managing relationships between suppliers, manufacturer and customers

8.3.3 Premium Car Co

The major developments at Premium Car Co are summarised in table 8.4. Like the other two case companies, Premium Car Co has to a large extent outsourced its production processes. The complexity of the cars has increased significantly, and their manufacturability has been poor. Quality assurance is mainly achieved by means of end-of-line inspections.

Table 8.4: Developments over time at Premium Car Co

Past	Present	Future
▪ Simple products	▪ Very complex products	▪ Reduced product complexity
▪ Focus on technical quality issues	▪ Growing importance of emotional quality issues	▪ Growing importance of emotional quality issues
▪ Poor product focus	▪ Strong product focus	▪ Strong product focus
▪ Poor process focus	▪ Poor process focus	▪ Strong process focus
▪ Production in-house	▪ Production to a large extent outsourced	▪ Production to a large extent outsourced
▪ Few data for decision making	▪ Few data for decision making	▪ Data-driven decision making
▪ Poor manufacturability	▪ Poor manufacturability	▪ Good manufacturability
▪ Radical changes	▪ Radical changes	▪ Gradual improvements
▪ Many end-of-line quality inspections	▪ Many end-of-line quality inspections	▪ Few end-of-line quality inspections
▪ Few quality checks embedded in assembly process	▪ Few quality checks embedded in assembly process	▪ Many quality checks embedded in assembly process

8.4 Application of the Research Model

The developments that have taken place in the quality management systems at each of the three case companies have been presented and discussed in the case chapters (see chapters 5 to 7). In this section, these developments are interpreted in terms of Simons' four levers of control model, which is used as the research model throughout this research (see chapter 4). The application of the research model to the case studies has been explained in detail in chapter 4 (see section 4.5.3). The most important steps are summarised below:

- Based on the developments and changes that have taken place over time at a case company, the effects on quality management at that company have been analysed. The systems that have been used at any moment in time by the case company to manage quality have been positioned in the four quadrants of the Simons model (i.e. beliefs systems, boundary systems, diagnostic control systems, and interactive control systems) by assessing the focus of each of these systems. Some elements of the quality management system may fit more than one quadrant of the Simons model, however, they have been grouped on the basis of their major focus, which is based on discussions with academic quality experts and the managers of the case company.

- Some of the quality management systems are related to each other, in the sense that they aim to manage the same business aspect but at different moments in time. These quality management systems have been connected to each other by means of arrows, in order to indicate that the emphasis has shifted over time from one system to the other. By doing so, trends emerge that indicate which levers of Simons' control model were important at different moments in time.

- Possible future trends have been identified as well, based on the current developments and the interviewees' expectations about developments that are planned for the near future.

The whole process of applying the research model to the case study findings is based on discussions between the two interviewers, the two academic quality experts, and the interviewed managers. The classification of quality management systems under the different levers of Simons' control model has been a challenging task, because consensus needed to be reached with everybody involved.

The results of this process are presented per case company in the following sections. The figures used to visualise the developments in quality management systems contain solid arrows and dashed arrows. The solid arrows indicate that a shift in emphasis from one system to the next has been completed. However, this does not mean that the previous system has been abandoned altogether, but only that the new system has become the main focus at the expense of the previous system. The dashed arrows indicate that a shift in emphasis from one system to the next has been planned (or is in progress) but not yet completed.

Some of the current quality management systems that have recently been implemented do not have a preceding system because, in the past, the case company did not have any system in place that was focused at the same business aspect. In these cases there is no arrow leading to the mentioned quality management system. If no new system is planned for the future as well, there is also no dashed arrow leading from the mentioned system, which is indicated by an asterisk behind the system's description.

8.4.1 Heavy Truck Co

The application of the research model to Heavy Truck Co has lead to a number of findings, which are visualised in figure 8.1. The left column indicates the business aspects for which quality management systems have been found to be in place. These business aspects are in line with the findings in the case study chapter (see table 5.4).

The part of the header row to the right of the double line contains the four control levers of the research model. In the remainder of the table, the quality management systems for each business aspect are categorised under the four control levers. The arrows and asterisks indicate the developments over time, as explained in section 8.4. Following the figure, the rationale for this categorisation is discussed in more detail.

Figure 8.1: Application of the research model to Heavy Truck Co

Business aspect	Beliefs systems	Interactive control systems	Boundary systems	Diagnostic control systems
Design process		Supplier involvement in design process		In-house design
Man vs. machine		Shop floor employees involved in problem solving and improvement✱		Processes man independent✱
Quality of supplies				Inspection of incoming supplies Quality agreements Supplier readiness reviews
Improvement approach		Improvement of designs		Six Sigma improvement approach
Traceability				Recall of all trucks that may have a defect Traceability of tasks and components
Process checks			Engine assembly manual with check list	Electronic manual to determine if checks have taken place.

indicates a realised development; indicates a planned development;
✱ indicates that no prior quality management system was in place and no future system is planned

Design Process

Heavy Truck Co has moved from in-house design, which was managed by setting targets and checking if these targets were met, to a design process that involves interacting with suppliers and joint problem solving.

Man vs. Machine

In the past, there was no specific strategy in place at Heavy Truck Co for the balance between employees and automation. Currently, the daily operations have been made man independent by installing equipment that checks every task with pre-set standards and reports any deviations. At the same time, improvement processes have developed from top-down implementations to team processes that are driven by the input of shop floor employees.

Quality of Supplies

In the distant past, Heavy Truck Co used to inspect incoming supplies to check whether their quality was good. Later on, Heavy Truck Co and its suppliers signed quality agreements that include clear and measurable targets for defect levels. More recently, Heavy Truck Co has started to assess the capabilities of suppliers to produce supplies in the right volumes and the right quality. These assessments use a set of criteria to determine the capabilities of suppliers, which are compared to the necessary capabilities for supplying components to Heavy Truck Co.

Improvement Approach

In the past, Heavy Truck Co did not have a structured approach for improvements. After the take-over, the Six Sigma improvement approach was introduced. Six Sigma is used within a clear boundary, which is the need to reduce costs. However, at the same time the Six Sigma approach itself is clearly a diagnostic system, in the sense that it prescribes the steps to be taken and compares realised savings to predicted savings. For the future, Heavy Truck Co's management plans to achieve costs savings with Six Sigma improvement projects that are aimed at preventing costs during the design stage.

Traceability

When a structural defect is found in a truck that has been sold in the past, Heavy Truck Co may have to recall many trucks because it does not always have a clear overview of all trucks that may be affected by the defect. In these cases, Heavy Truck Co will recall all trucks that have been produced during the period in which the defect part has been used. For the future, Heavy Truck Co's management plans to improve this situation by tracking all tasks that have been completed on a truck, as well as all components that have been procured from suppliers. This will allow Heavy Truck Co to pinpoint exactly all trucks that need to be recalled because of a defect.

Process Checks

The quality control system for the engine assembly department is currently a check list that demands that employees check many boxes, but the number of checks is too large. Consequently, employees check all boxes before they start working on an engine, and there is no system to guarantee that the checks actually took place. For the near future, Heavy Truck Co plans to develop a control system that is able to determine if these checks have been completed, and can act upon failed checks.

8.4.2 Small Car Co

The application of the research model to Small Car Co has lead to a number of findings, which are visualised in figure 8.2. As explained in the Heavy Truck Co section (see 8.4.1), the left column indicates the business aspects for which quality management systems have been found to be in place. These business aspects are taken from the findings in the case study chapter (see table 6.4).

The structure of the figure has been explained in section 8.4.1.

Figure 8.2: Application of the research model to Small Car Co

Business aspect	Beliefs systems	Interactive control systems	Boundary systems	Diagnostic control systems
Limits to car assembly			Limits to car assembly clearly communicated to corporate customers*	
Importance of shop floor employees	Shop floor employees responsible for quality			Automation of processes to prevent quality problems
Product responsibility			Quality gates indicate who is responsible*	
Hiring policy			Newly hired people on temporary contract Temporary contracts not allowed to exceed 30% of workforce	
Defect supplies policy			Suppliers fined if they cause line stoppage.	Defect supplies taken from production line and replaced from stock
Problem solving approach		Cross-organisational teams, and familiar people at key supplier positions		Internal problem solving
Design process		Supplier involvement in design process		In-house design
Process problems		Prototype assembly to solve process problems before pilot production*		
Supply chain management			First tier suppliers manage their supply chain	Small Car Co manages whole supply chain

indicates a realised development; indicates a planned development;

* indicates that no prior quality management system was in place and no future system is planned

Limits to Car Assembly

In the past, Small Car Co would rarely receive requests from corporate customers to assemble car variants that are technically very complex, or even impossible to manufacture. Currently, Small Car Co clearly indicates the boundaries of engineering and design to its corporate customers. Any car variant that would result in crossing the boundaries will not be manufactured.

Importance of Shop Floor Employees

The management clearly stimulates the belief among Small Car Co's shop floor employees that they are of key importance for the quality of the end products. In the past the organisation used to replace labour with automation, however, the limits of this approach have become clear to the management. Currently, shop floor employees are motivated to cooperate on problem solving and improvements. In an interactive way they are working together with engineers and suppliers to improve products and processes.

Product Responsibility

The responsibility for the products has been made clear by introducing quality gates in the assembly process. These gates indicate the boundaries of a person's or department's responsibility.

Hiring Policy

In the past, Small Car Co would hire all new employees on a temporary contract, in order to remain flexible. However, over time the management has learnt that the commitment of employees who work on a temporary contract is less than employees on a fixed contract. Therefore, the management does not allow the share of employees on a temporary contract to exceed 30% of the total workforce.

Defect Supplies Policy

Defect supplies used to be replaced with good ones from the warehouses of Small Car Co. Today, suppliers know that they will receive a bill if they cause a stoppage of the production line because of defect supplies. So, the current system sets clear boundaries within which the suppliers have to operate.

Problem Solving Approach

In the past, Small Car Co would solve its problems internally by means of structured problem solving tools. Today, the complex products require cross-organisational teams of various specialists who cooperate on problem solving.

Design Process

The design process has undergone a similar development as the problem solving approach. Design used to be done in-house by specialists who would adhere to agreed procedures, and correct any deviations from these procedures. Today, the design process requires the involvement of supplier experts in frequent meetings, in order to deal with the complexities of contemporary cars.

Process Problems

Solving process problems during pilot production of a car model used to be the normal way of working at Small Car Co. However, the need to be efficient right from the start of production required Small Car Co to implement a control system to improve the processes before pilot production. This approach involves installing components on an artificial car body, and involves managers, engineers and shop floor employees. Together, they try to find the best solution to all problems they come across.

Supply Chain Management

Management of the supply chain had traditionally been done by Small Car Co, by measuring the performance of suppliers and acting upon any deviations from agreements. However, the length of the supply chain has increased over the years and the complexity of managing it has increased as well. Therefore, Small Car Co now holds the first tier suppliers responsible for managing their supply chains. These first tier suppliers have to perform within the set boundaries, otherwise they have to explain during one of Small Car Co's management meetings what they are doing wrong. So, Small Car Co only sets the boundaries and will not control these suppliers diagnostically, because it has no direct control over punishment and reward systems at the suppliers.

8.4.3 Premium Car Co

The findings that have resulted from applying the research model to the Premium Car Co case are visualised in figure 8.3. As in figures 8.1 and 8.2, the left column indicates the business aspects for which quality management systems have been found to be in place. These business aspects are based on the findings in the case study chapter (see table 7.4).

The structure of the figure has been explained in section 8.4.1.

Figure 8.3: Application of the research model to Premium Car Co

Business aspect	Beliefs systems	Interactive control systems	Boundary systems	Diagnostic control systems
Supply chain management		Cooperation with suppliers before and during assembly	Suppliers are responsible for all quality problems with supplies	
Design focus			Design for manufacturing✱	
Decision making				Data-driven decision making✱
Quality assurance				Quality assurance by means of end-of-line inspections Checks embedded in assembly process
Quality focus	Engineers determine quality of the cars Customers determine quality of the cars			
Importance of shop floor employees	Employees drive processes	Employees are important for high quality		Robots necessary for production and inspection

indicates a realised development; indicates a planned development;
✱ indicates that no prior quality management system was in place and no future system is planned

Supply Chain Management

In the current situation, Premium Car Co's suppliers are held responsible for any quality problem that is related to procured components. This is a clear rule for anyone involved, and suppliers know that they have to solve problems by themselves or prove to Premium Car Co that the cause of the problems is not in the supplies. However, Premium Car Co's management has realised that many supplier problems are related to the design of the cars. Therefore, Premium Car Co plans to cooperate with its suppliers before and during the assembly process, because this is beneficial to both parties involved.

Design Focus

The management believes that many quality problems with its cars are the result of the poor manufacturability of the cars. The cars have traditionally been designed from the customer's perspective, which has resulted in designs that are difficult to manufacture. For the near future, Premium Car Co's management plans to pay more attention to the manufacturing aspects of its car models, by imposing restraints on the design of the cars. So, the designers may have to compromise their designs if the engineers expect problems for the manufacturability of the car.

Decision Making

Decision making at Premium Car Co has traditionally been ad-hoc and based on limited data. Premium Car Co's managers plan to increase the amount of data that is collected, and use those data for considered and transparent decision making that makes people accountable for their decisions.

Quality Assurance

Currently, Premium Car Co relies heavily on end-of-line inspections to guarantee the quality of the cars. Each completed car is checked against an elaborate check list, and any defects are resolved. This is an inefficient approach to quality assurance. Therefore, Premium Car Co plans to embed more quality checks in the assembly process, which require shop floor employees to check each other's work and immediately report any defects found.

Quality Focus

Premium Car Co is an organisation with a strong engineering heritage, in which the engineers traditionally determined what a good quality car was. Today, this belief has changed and the customers have replaced the engineers when it comes to deciding what a good quality car is.

Importance of Shop Floor Employees

In the past, robots would be indispensable for manufacturing high quality cars and checking the work of the shop floor employees. However, the increased complexity of the manufacturing process has reduced the usefulness of robots, and increased the importance of the shop floor employees. Shop floor employees are now involved in discussions about problem solving and improvement, together with the management and engineers. Premium Car Co's management plans to give shop floor employees even more responsibilities, and spreads the belief that shop floor employees should drive the processes in the plant.

8.5 Summary

The case studies have been undertaken to understand how the two trends of increasing product variety and shortening product life cycles have an influence on car manufacturers, and what this means for the quality management systems that are in place at these manufacturers (see case methodology in chapter 4). The nature and extent of the influence of developments in product variety and product life cycles have both been discussed in this chapter. To clarify the nature of product variety and product life cycle trends, they have been structured along several scales that have resulted from the case study examinations.

The extent to which the three case companies have been influenced by increasing product variety and shortening product life cycles is different for each case (see table 8.1). Similarly, the extent to which the case companies have modified their quality management systems over time is different for each case as well, because figures 8.1 to 8.3 show different patterns of change for each of the case companies. Combining these patterns with the differing influences of product variety and life cycle trends, some tentative conclusions can be drawn:

1. Heavy Truck Co has experienced the least influence of both increasing product variety, as well as shortening product life cycles. At the same time, its quality management systems have remained predominantly diagnostic, with only few interactive systems in place. The case examination makes clear that quality management is still important for Heavy Truck Co, and that the company has achieved exceptional market success. Therefore, it appears that diagnostic quality management systems may be sufficient for organisations that experience a limited influence of product variety and life cycle trends. This is in line with the hypotheses presented in section 4.5.2.

2. Small Car Co has experienced a strong influence of shortening product life cycles, while the influence of increasing product variety has been much less profound. At the same time, the main focus of Small Car Co's quality management systems has shifted away from diagnostic systems towards interactive systems, combined with boundary systems. The case examination has shown that quality management is essential for Small Car Co to make a profit. Therefore, it appears that in a situation of shortening product life cycles it may not be sufficient anymore to rely on diagnostic quality management systems. Instead, it is necessary to approach quality management in an interactive way, within strict and clear boundaries. This is, to an extent, in line with the hypotheses presented in section 4.5.2.

3. Premium Car Co has experienced a strong influence of increasing product variety, while the influence of shortening product life cycles has been much less profound. At the same time, Premium Car Co's quality management systems have remained a mix of all four types of control systems. The case examination has made clear that quality management is important to qualify for the premium label, because customers expect a quality product for their money. It has also become clear that Premium Car Co is regarded by its owner as being highly successful in terms of the quality of its cars. Therefore, it appears that in a situation of increasing product variety there may be no need to concentrate on interactive control systems, as was hypothesised on the basis of the research model (see section 4.5.2). However, focusing solely on diagnostic control systems may not be a good strategy either. Still, this is an indication that increasing product variety may have a different influence on quality management systems than product life cycles.

The case study analysis has made clear that more research is needed on the relationship between, on the one hand, product variety and life cycles and, on the other hand, quality management systems. The findings from the Premium Car Co case appear to be at odds with the hypotheses, although it is not clear why this is the case. An issue that may play a role in the outcomes of the three case studies is the maturity of each company in using quality management systems. The limited number of quality checks embedded in the assembly process at Premium Car Co, compared to the other two cases, may be an indication that Premium Car Co's quality systems are less mature than those of the other companies. Therefore, issues that require further research are:

- The differences between the effects of increasing product variety and the effects of shortening product life cycles.
- The effect that the quality maturity of an organisation has on its inclination/ability to adapt the existing quality management systems.

These issues have been investigated further in the next stage of this research, which is a questionnaire survey. On the basis of the results from the three case studies a questionnaire survey has been developed. This survey has been sent out to a wider sample of firms in the automotive industry, to assess to what extent the case study findings can be found in a larger sample of firms. The details of this questionnaire survey and its outcomes are discussed in chapter 9.

9 Questionnaire Survey

9.1 Introduction

This chapter describes the questionnaire survey that has been undertaken to quantify the effects of increasing product variety and shortening product life cycles on quality management systems. The design of the questionnaire is outlined, and the sample described. Thereafter, the analyses of the gathered data are presented and discussed. Finally, conclusions are drawn on the basis of the questionnaire survey.

9.2 Questionnaire Design

To empirically test the hypothesised shift towards the increasing importance of interactive control systems in a situation of increasing product variety and shortening product life cycles, a questionnaire survey has been undertaken. In order to be able to quantify the importance of the different kinds of control systems, a relatively large number of respondents is needed. However, the number of car manufacturing sites in Western Europe is limited (Automotive News, 2004), and a global survey could introduce regional differences (e.g. in the USA cars are usually sold from stock and not built-to-order). Therefore, the suppliers in the European automotive industry could provide a better sample. The case study analysis in chapter 8 has indicated that the role of suppliers in the quality of the end product has increased significantly over the last decade. Moreover, the interviewed suppliers have indicated that they are experiencing the same developments in product variety and life cycles as car manufacturers. In addition, the number of automotive suppliers in Western Europe is high, compared to the number of car manufacturers. Therefore, the questionnaire survey has been undertaken among a sample of European automotive suppliers.

The design of the questionnaire follows the detailed case study work presented in chapters 5 to 8, and a review of literature about the automotive supplier industry. Simons' four levers of control model has been used as the research model for the questionnaire survey. The questionnaire probes if respondents' organisations are increasing the number of product variants they offer and if the life cycles of their products are becoming shorter. Consequently, respondents are asked if these two developments have any influence on a range of organisational outcomes. The extent to which quality management has been important in the past and to what extent it still is important today is also examined. Finally, respondents are asked which quality control mechanisms were important in the past and which are important today, and what influence they have had on indicators of organisational performance. On the basis of this structure, it is possible to assess if organisations shift their emphasis in terms of the levers of Simons' control model when the environment becomes more complex and unpredictable.

The questionnaire consists of six blocks of questions (see appendix 9.1):

1. Characteristics of the respondent and his organisation (questions 1 to 8)

2. Perceptions about product variety and product life cycle length (questions 9 to 13)

3. The effects of changes in product variety and life cycle length on a range of organisational outcomes (questions 14 and 15)

4. The importance of quality management to the organisation, and the maturity of the organisation in terms of quality management (questions 16 and 17)

5. The way in which the organisation manages and controls quality in terms of the research model (question 18)

6. The effects on several performance indicators (question 19)

Most questions are closed questions (i.e. respondents are offered a number of alternatives to choose from), although some questions offer respondents the option to fill out an answer that is not listed. The questions about the respondent's job title (question 6) and the product life cycle length (question 12) are open questions. Most questions ask the respondents to give their opinions about a list of statements. The answering categories for these questions use 5-point Likert scales, for example, ranging from 1 = completely disagree to 5 = completely agree (Likert, 1932). This type of scale is generally accepted among researchers (Miltenburg, 2003).

Most questions also ask the respondents to compare the current situation at their organisations with the situation that existed ten years ago. This approach is in line with the approach that has been applied to the case study interviews (see chapter 4), and will allow for comparisons between the case studies and the questionnaire survey. The approach of comparing today with ten years ago has been taken before in empirical research (see Pine, 1993), and the experience with the case studies has been positive because interviewees had generally no problem to go back in time even further. Moreover, a shorter period of time would be too short in the automotive industry because, for example, five years ago a supplier may have been manufacturing exactly the same component for the same car as it does today. So, to be able to see the changes in product variety and product life cycles, a longer period of time needs to be taken into account.

Question 18 is very important for this study, since it contains the items that represent the four levers of the research model (see chapter 4). Therefore, the items in this question have been developed in two separate ways:

1. Based on the results from the case study analysis

2. Independently by experts who know Simons' control model and developments in quality management over the last decades, but who did not start from product variety and product life cycle time.

So, question 18 is a summation of questions from both these sources.

The resulting questionnaire was pilot tested, in order to assess if the questions were understandable and relevant. Both practitioners from the automotive industry and academic experts were involved in the pilot testing of the questionnaire. All suppliers that had been interviewed during the case study research were asked to comment on the questionnaire, and the quality managers at each of the case companies were asked to comment as well. The questionnaire was also discussed with four academic experts. Suggestions resulting from these tests have been incorporated in the final version of the questionnaire.

The questionnaire was sent to a sample of suppliers to automotive Original Equipment Manufacturers (OEMs) based in the United Kingdom, Germany, Belgium and the Netherlands. This mailing list of OEM suppliers was purchased from a commercial market research bureau with an international reputation. OEM suppliers are part of the automotive supply chain and are therefore aware of the quality demands of the OEMs. Automotive suppliers that supply the after-market or manufacturers of special vehicles are believed to operate under different circumstances than the OEM suppliers. Therefore, only OEM suppliers were targeted by the questionnaire.

Two versions of the questionnaire were used:

1. An English version (see appendix 9.1) for the United Kingdom, Belgium and the Netherlands.

2. A German version (see appendix 9.2) for Germany.

The Dutch and Belgian suppliers are a minority of the total sample, and previous questionnaire surveys have shown that respondents in these countries have no problems with questionnaires in English (see Van der Wiele et al., 2005). Therefore, the Dutch and Belgian suppliers were sent an English version of the questionnaire. The majority of suppliers in the sample are German, and they were expected to have more problems with a questionnaire in English. Cooperation with Prof. dr. Klaus Zink and Ulrich Steimle from the University of Kaiserslautern in Germany resulted in the decision to have the questionnaire translated in German. The questionnaire was translated by a professional translator, and thereafter checked by Ulrich Steimle for problems with scientific and industry specific jargon. Both questionnaires were sent out from the Erasmus University in Rotterdam, but different cover letters were used (see appendices 9.1 and 9.2).

9.3 Questionnaire Analysis

This section presents the results of the questionnaire survey. The sample and response rate are discussed first, and descriptive statistics are presented. Thereafter, multivariate analyses are presented and discussed.

9.3.1 Sample and Response Rate

Table 9.1 provides details of the response rate. It also shows how many questionnaires were either undeliverable, or sent to companies that do not supply to OEMs. Subtracting the latter two groups from the initial sample, results in the net sample size. The response rates are percentages of the net sample size.

Table 9.1: Sample and response rate

Country	Sent out	Undeliverable	Not in target group	Net sample size	Response
Netherlands	567 *100%*	24 *4.2%*	5 *0.9%*	538 *94.9%*	6 *1.1%*
Belgium	303 *100%*	22 *7.3%*	2 *0.7%*	279 *92.1%*	3 *1.1%*
United Kingdom	1,714 *100%*	145 *8.5%*	8 *0.5%*	1,561 *91.1%*	28 *1.8%*
Germany	2,174 *100%*	139 *6.4%*	16 *0.7%*	2,019 *92.9%*	61 *3.0%*
Total	4,758 *100%*	330 *6.9%*	31 *0.7%*	4,397 *92.4%*	98 *2.2%*

The table shows that the response rate is very low, which will be discussed and analysed in the next section. Another issue that becomes clear from table 9.1 is the large difference between the response rate for Germany and the ones for the other countries. An explanation for this difference may be the likelihood that a supplier company employs a quality manager. The questionnaire was addressed to the quality manager or, if there is nobody with such role, to the most senior person who is responsible for quality management. Still, some organisations may have paid very little attention to the questionnaire because they have no formal quality manager. According to the quality management experts from the University of Kaiserslautern in Germany, it is very likely for German automotive suppliers to have a formal quality manager. Possibly, automotive suppliers from the other three countries are less likely to have a quality manager, which may explain some of the difference in the response rates. However, no academic research has been found to support this expectancy.

9.3.2 Analysis of Non-Response

The response rates are all very low. The majority of companies on the mailing list did appear to be operating in the automotive industry. However, with hindsight, they are very likely not to supply the actual OEMs (i.e. the car manufacturers) but to supply the after-market, or to manufacture special vehicles/trailers for individual companies, or to be involved in motor sports, or to do repairs on vehicles/trailers.

To gain an insight into the reasons for the low response rates, 53 random non-respondents were contacted by phone to ask for their motives as to why they did not fill out the questionnaire. The reasons for not responding are listed in table 9.2. Twenty three (43%) of the 53 companies do not supply OEMs, which is a clear indication that the mailing list was strongly contaminated. There are also 15 companies (28%) that do not exist anymore or ceased their operations at the site. Other reasons include: some organisations do not allow their employees to participate in any kind of research, and some companies are not involved in the automotive industry at all.

So, it can be concluded that many organisations on the mailing list are not part of the relevant sample (more than 75% based on ‘not supplying to OEMs’, ‘not supplying automotive products at all’ and ‘do not exist anymore’), and this can help explain the low response to the questionnaire survey. When only the relevant sample is taken into account, the response rate is considerably higher, and more in line with questionnaire surveys in existing management literature (Krumwiede, 1998; Pagell et al., 2004; Sidhu, 2004).

Table 9.2: Reasons for not responding to the questionnaire

N	%	Reason for not responding
23	43.4%	Supply automotive products, but not to OEMs. So, they: ▪ supply the aftermarket, or ▪ manufacture special vehicles/trailers for individual companies, or ▪ are involved in motor sports, or ▪ do repairs to vehicles/trailers
15	28.3%	Do not exist anymore or ceased operations at the site
4	7.5%	Were repeatedly unable to connect with the relevant person
3	5.7%	Did not want to answer any questions
3	5.7%	Are not allowed to participate in research because of a company policy
2	3.8%	Do not supply automotive products at all
2	3.8%	Did not recall receiving the questionnaire
1	1.9%	Started filling out the questionnaire but did not finish and later on threw it away
53	100%	Total number of organisations called

From the analysis of the non-response, it can be concluded that the mailing list was strongly contaminated. The mailing list was bought from an international commercial market research bureau, and it was advertised as a mailing list of automotive OEM suppliers. It was anticipated that such a list may not be as ideal as using a very specific list from, for example, an association of automotive suppliers. However, the latter list was not available, although many possibilities have been considered:

- Mailing lists of suppliers to the three case study companies might have been possible. However, the case study companies were very reluctant to share information about all their suppliers. They consider this to be confidential information. Even the exact number of suppliers is something they would not want their competitors to know. Moreover, in two of the three case companies the contact persons had moved to another position and sometimes even to another organisation. This would make it even more difficult to obtain the lists of suppliers. A methodological problem with these lists is the bias that they would give to the response because some suppliers are solely dedicated to one customer. So, the three case companies may for many suppliers be the only (or major) customer, which means that the case companies have a very strong influence on the way these plants are managed. This would mean that the questionnaire survey is an expansion of the case research, which is not the intention because the questionnaire survey is meant to find quantitative support among a wider sample of unrelated organisations.

- Mailing lists from associations of automotive suppliers would probably be good. However, no association in the Netherlands, United Kingdom, Germany or Belgium was willing or able to sell addresses. The European Association of Automotive Suppliers (CLEPA) was also not willing or able to sell addresses. Chambers of commerce in the four countries did not have specific departments for the automotive industry either.

So, the only option that remained was to buy a mailing list from a market research bureau. Several of these bureaus were considered, after which the most attractive offer was accepted.

However disappointing the quality of the mailing list may be, what matters most is not so much the response rate itself but the quality of the responses. Many quality managers of renowned suppliers have taken the time to fill out the complete questionnaire and have chosen to attach their business card to the questionnaire in order to be informed about the results. This tells something about their commitment and their interest in the outcomes of this research.

9.3.3 Descriptive Statistics

The respondents' organisations are predominantly manufacturing organisations (N=73), while some are pure service organisations (N=14) and others are a mixture of manufacturing and services (N=11). The majority of organisations are either privately owned (61%) or part of a large group (37%), and most have between 100 and 500 employees (36%). The average organisation has been operating in the automotive industry for 11 to 15 years, whilst respondents have, on average, been working for 6 to 10 years in the automotive industry.

The car OEMs most often supplied by these suppliers are Ford (N=53), DaimlerChrysler (N=52), Volkswagen (N=50), General Motors (N=40) and BMW (N=40), see figure 9.1. The truck OEMs most often supplied by the suppliers are DaimlerChrysler Trucks (N=30), Volvo Trucks (N=25) and MAN (N=21), see figure 9.2.

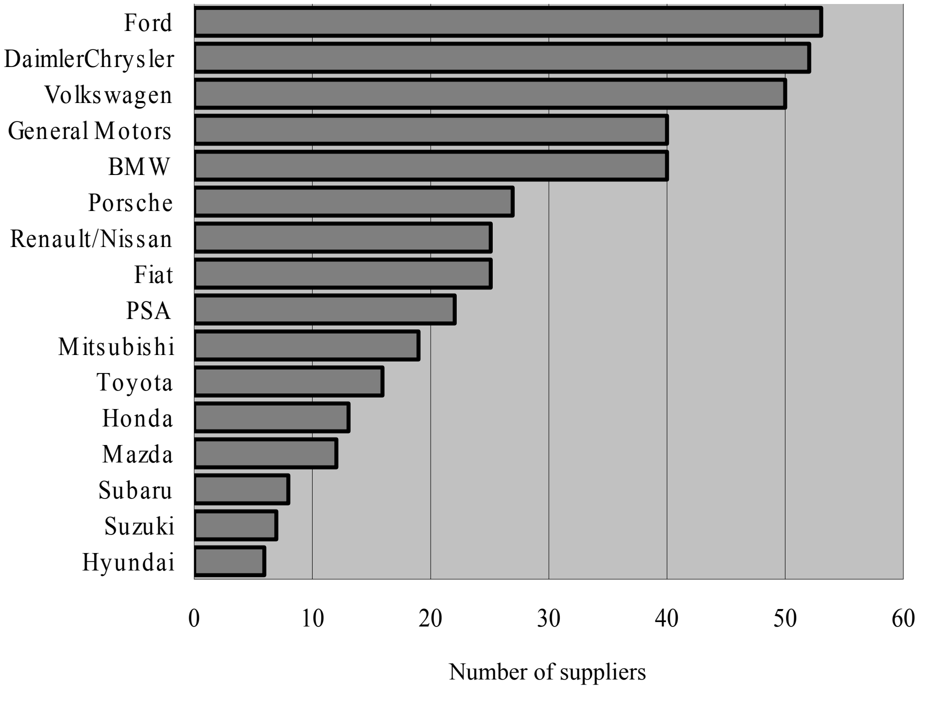


Figure 9.1: Car OEMs supplied by the respondents' organisations

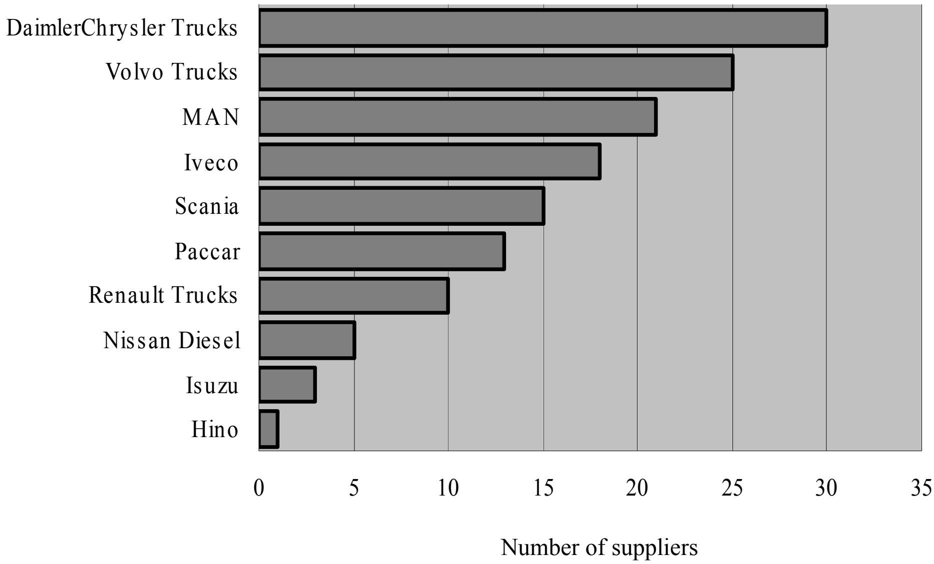


Figure 9.2: Truck OEMs supplied by the respondents' organisations

Most suppliers manufacture power trains (36%), chassis systems (27%), or exterior trim and body parts (25%).

9.3.4 Developments in Product Variety and Life Cycles

Respondents were asked to indicate the average shift in the length of their products' life cycles over the last ten years. These shifts range from life cycles that have become 15 years shorter to life cycles that have become 10 years longer. On average, the product life cycles have become significantly shorter (P-value of 0.02) over the last ten years by just over a year (from an average of 9.13 years to 8.07 years). This reduction of life cycle length is in line with the findings of Von Corswant and Fredriksson (2002). However, the absolute life cycle lengths are not in line with their findings, because they found shorter life cycles. This may be the result of the small sample (N=16) used by Von Corswant and Fredriksson (2002). For the future, respondents expect product life cycles to become somewhat shorter, and the standard deviation of 0.88 indicates that there is not much disagreement between the respondents about this trend.

Respondents also indicated that over the last ten years their organisations have increased the product variety they offer, and they expect to increase it even more in the future. However, the speed of increase is expected to be significantly slower in the future than it has been in the past (P-value of 0.00).

Respondents' reactions to a number of statements about product variety and product life cycles (see table 9.3) indicate that many significant developments have taken place over the last decade. The table presents the P-values of a t-test between today and ten years ago, and many developments are even valid on a 99% significance interval. Product variety has increased over the last ten years and product life cycles have become shorter (although they are still perceived to be long in absolute terms). Over the last ten years, the predictability of customer demand has become significantly less, and demand is now also changing more rapidly than ten years ago. Moreover, the need to respond quickly to changing customer demands with new or modified products has become absolutely critical over the last ten years. Another finding is that customers are not willing to pay extra for additional product variety, while some were still willing to do so ten years ago. Product innovations are currently very important to the respondents' organisations, and significantly more so than ten years ago. The demands on suppliers are perceived to be very high, and significantly more so than ten years ago: competition has increased, and the demands of customers on quality, costs and delivery performance are tough. At the same time, customers have become more willing to share sensitive information with suppliers. The production processes at the suppliers have become more flexible and lean, with smaller batch sizes and lower stocks of supplies and finished goods.

Table 9.3: Developments in product variety and product life cycles

Statement	Today* Mean	Ten years ago* Mean	P-values**
Customer demand is predictable	2.54	3.36	0.000
Customer demand is changing rapidly	3.96	3.16	0.000
My plant offers products in a wide range of configurations	4.28	3.66	0.000
Customers are willing to pay extra for additional product variety	2.54	3.42	0.000
My plant offers more product variety than our competitors	3.70	3.32	0.003
Customers are actively assisting my plant in delivering product variety	2.84	2.92	0.531
Fashion trends and style have an influence on customer demand	3.10	2.76	0.000
It is important to respond quickly to changing customer demands with new or modified products	4.46	3.94	0.000
Our products have short life cycles	2.53	2.28	0.004
Product innovations are important to the success of my plant	4.25	3.85	0.000
Production technologies are changing rapidly	3.57	3.11	0.000
My plant is dependent on investments in technology	3.55	3.25	0.010
Customers dictate prices, conditions, and product features	4.06	3.36	0.000
Customers could not easily switch to an alternative supplier	3.27	3.11	0.163
Competition is strong	4.36	3.70	0.000
Demands of customers on quality are tough	4.59	4.02	0.000
Demands of customers on delivery performance are tough	4.68	3.95	0.000
Demands of customers on costs are tough	4.40	3.61	0.000
Our products meet our customers' needs and wants	4.51	4.26	0.000
Customers are willing to share sensitive information with my plant	3.55	3.37	0.045
Production processes in my plant are characterised by large batch sizes	2.63	2.87	0.042
My plant has flexible production processes	4.16	3.63	0.000
To cope with demand fluctuations my plant uses labour rather than automation	3.61	3.80	0.063
Stock levels of finished goods are large in my plant	2.45	3.00	0.000
Stock levels of supplies are large in my plant	2.61	3.28	0.000

* Degree of agreement with statement, both for today and ten years ago, on a 5-point scale from 1=completely disagree to 5=completely agree; ** P-values of the difference between today and ten years ago

Respondents indicated that the developments in product variety and product life cycles have had a significant and profound impact on the management of a range of organisational outcomes. The effects of changes in product variety on organisational outcomes are presented in table 9.4, and the effects of changes in product life cycle length are presented in table 9.5. Respondents claim that the quality of their products and processes is more difficult to manage in a situation of many product variants. A short product life cycle length also has a negative influence on the ability to manage the quality of the product, but no significant influence on the ability to manage the quality of the processes. According to the respondents, the negative influence of product variety on managing the quality of products and processes is currently significantly stronger than the influence of shortening product life cycles (P-values of 0.00).

Apart from these differences, developments in product variety and life cycles tend to have a similar influence on the management of organisational outcomes. Both have made it significantly more difficult to manage costs, and they both have made it more difficult to manage the length of product development processes. Surprisingly, increasing product variety and shortening product life cycles have not significantly complicated the management of employee performance. However, the management of the performance of sub-suppliers has become significantly more difficult. The same goes for managing the satisfaction of customers and employees, although the latter is only significantly influenced by developments in product variety. Finally, managing the time needed for interaction with customers and sub-suppliers has become significantly more difficult as a result of developments in product variety and product life cycles. Notwithstanding all these difficulties, neither product variety, nor product life cycles have a significant impact on the organisations' abilities to manage the number of product recalls. This is an important finding, given the major consequences a product recall currently has on suppliers, both in terms of costs as well as reputation.

Table 9.4: Effects of changes in product variety on organisational outcomes

Organisational outcome	Today* Mean	Ten years ago* Mean	P-values**
Quality of our products	3.49	2.97	0.000
Quality of our processes	3.38	2.98	0.010
Delivery performance of my plant	3.19	2.97	0.098
Costs of my plant	3.78	3.13	0.000
Costs of our final products	3.69	3.05	0.000
Length of our product development processes	3.49	3.03	0.003
Employee performance of my plant	2.93	2.79	0.272
The performance of our suppliers	3.33	3.01	0.007
Number of product recalls by my plant	2.01	2.08	0.489
Product demand fluctuations	3.38	3.01	0.005
Satisfaction of our customers	3.01	2.60	0.002
Satisfaction of our employees	3.02	2.70	0.009
Employee knowledge level	3.10	2.84	0.063
Time needed for interaction with our customers	3.52	2.90	0.000
Time needed for interaction with our suppliers	3.44	2.88	0.000

* Extent to which an organisational outcome is easy to manage, both today and ten years ago, on a 5-point scale from 1=very easy to manage, to 5=very difficult to manage;
** P-values of the difference between today and ten years ago

Table 9.5: Effects of changes in life cycle length on organisational outcomes

Organisational outcome	Today* Mean	Ten years ago* Mean	P-values**
Quality of our products	2.95	2.56	0.003
Quality of our processes	2.98	2.76	0.101
Delivery performance of my plant	2.95	2.73	0.083
Costs of my plant	3.30	2.88	0.006
Costs of our final products	3.38	2.93	0.003
Length of our product development processes	3.30	2.74	0.000
Employee performance of my plant	2.87	2.78	0.440
The performance of our suppliers	3.15	2.90	0.045
Number of product recalls by my plant	2.28	2.29	0.906
Product demand fluctuations	3.18	2.79	0.002
Satisfaction of our customers	2.79	2.48	0.010
Satisfaction of our employees	2.80	2.67	0.206
Employee knowledge level	2.84	2.64	0.114
Time needed for interaction with our customers	3.30	2.74	0.000
Time needed for interaction with our suppliers	3.30	2.85	0.001

* Extent to which an organisational outcome is easy to manage, both today and ten years ago, on a 5-point scale from 1=very easy to manage, to 5=very difficult to manage;
** P-values of the difference between today and ten years ago

The difficulties with managing product and process quality are not the same for all respondents. It appears that managing quality is more difficult for organisations whose product life cycles have become shorter over the last ten years, then for organisations whose product life cycles have become longer (see figure 9.3). The figure shows on the horizontal axis the extent to which it is difficult to manage product quality, and on the vertical axis the extent to which it is difficult to manage process quality. In the figure, the respondents are grouped in five categories on the basis of the relative increase in product life cycle length. The respondents that have seen an increase in product life cycle length have least difficulties with managing product and process quality, while the respondents that have seen a decrease in product life cycle length have more difficulties with managing both product and process quality. This figure is supported by Pearson correlations between, on the one hand, the five life cycle categories and, on the other hand, the difficulty of managing product quality (r=0.39, P-value of 0.00) and the difficulty of managing process quality (r=0.27, P-value of 0.01).

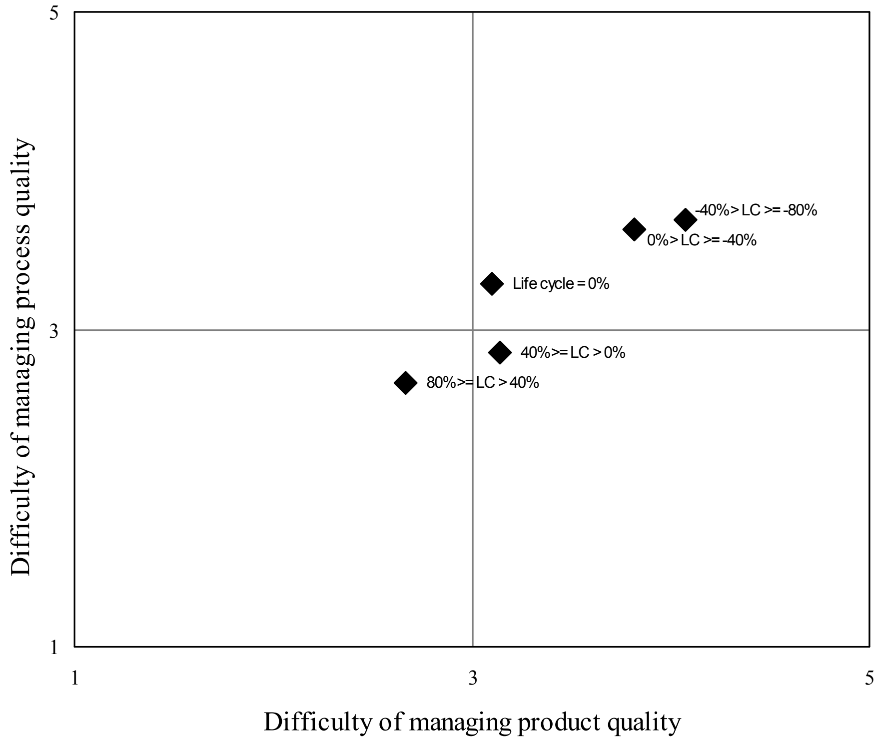


Figure 9.3: Product life cycle length and difficulty of managing quality

9.3.5 Developments in Quality Management

Quality management is currently very important for respondents' organisations (see table 9.6). Today, quality management is significantly more important than ten years ago although it was considered important then. The measurement of quality, both during the production process and thereafter, appears to be common practice today. Especially the measurement of quality during the production process receives much more attention today than it did ten years ago. More importantly, quality measurements currently take place significantly more often (P-value of 0.00) during the production process than at the end of the production process, while ten years ago there was no significant difference between the two approaches to quality checks.

The expertise of the quality department is currently rated higher than ten years ago. However, there is a positive correlation (r=0.20, P-value of 0.03) between the relative increase in life cycle length and the extent to which the expertise of the quality department is sufficient. This indicates that the expertise of the quality department is felt to be less sufficient in a situation of short product life cycles, when compared to a situation of long life cycles.

The quality of the products that the suppliers manufacture is positively judged by the suppliers themselves. The respondents also indicated that ten years ago the quality of the products was less. The customers of these supplier organisations seem to take quality seriously as well, since the scores for quality versus costs and quality versus delivery performance are around the neutral position (i.e. a 3 on a five point scale). Ten years ago these scores were virtually the same.

After delivery of the products to the customers, the suppliers have always remained responsible for these products, and this responsibility has even increased over the last ten years. The traceability of defect products back to their origin, has improved significantly over the last ten years.

Employee involvement has increased over the last decade, and is now at a high level. Employees operate in teams, they have clear improvement objectives, and they receive regular training to keep up with developments. Even training of sub-suppliers is seen as a responsibility, and significantly more so than ten years ago.

Suppliers have to involve specialists significantly more often than in the past, because of the manufacturing complexity.

Table 9.6: Developments in quality management

Statement	Today* Mean	Ten years ago* Mean	P-values**
The quality of our products is excellent	4.07	3.51	0.000
Quality problems are predictable	3.28	3.09	0.097
Our suppliers determine the quality of our final products	3.23	3.08	0.123
A defect free performance is essential for my plant to survive	4.55	4.04	0.000
It is a problem for my plant to keep the number of defects low	2.88	2.85	0.843
Customers are more focused on costs than on quality	3.27	3.24	0.869
Customers are more focused on delivery performance than on quality	2.93	2.91	0.813
After delivery of our products to our customers, my plant is not responsible for defects that occur	1.45	1.73	0.006
Quality management is important for my plant	4.63	3.73	0.000
The expertise of our quality department is sufficient	4.07	3.60	0.000
Our customers' accountants have a strong influence on the specifications of the products that my plant offers	2.91	2.72	0.019
My plant promotes teamwork	4.06	3.51	0.000
All our employees have clear improvement objectives	3.64	3.03	0.000
Training of our employees is necessary to keep up with developments	4.47	3.61	0.000
Training of our suppliers is seen as our responsibility	3.17	2.54	0.000
Fluctuations in customer demand have a negative influence on the quality of our products	2.42	2.39	0.747
Customers outsource products/processes that are not critical to them	3.17	2.67	0.000
Outsourcing of parts of the production process to specialists is essential to cope with manufacturing complexity	3.36	2.99	0.000
It is difficult to trace back the cause of a defect product to its origin	2.25	2.53	0.019
My plant measures quality during the production process	4.48	3.58	0.000
My plant measures quality at the end of the production process	4.08	3.81	0.018
Quality problems are often related to non-technical/emotional issues	3.01	2.94	0.483

* Degree of agreement with statement, both for today and ten years ago, on a 5-point scale from 1=completely disagree to 5=completely agree**; P-values of the difference between today and ten years ago

To assess the maturity of respondents' organisations in the management and improvement of quality, Crosby's well publicised quality management maturity grid has been utilised (Crosby, 1979). The categories in Crosby's maturity grid (i.e uncertainty, awakening, enlightenment, wisdom and certainty) have previously been translated in statements for the purpose of a questionnaire survey (see Van der Wiele, 1998). These statements have been used in the present survey as well. Respondents were asked to rate the maturity of their organisations on 5-point scales for each of the statements, see table 9.7.

The table makes clear that the lowest, as well as the highest categories of the grid have improved over the last decade. The suppliers know better why quality problems do and do not occur, and defect prevention has become a routine part of their operations. However, the scores for the second maturity category have not changed significantly over the last ten years. Apparently, respondents' organisations are still struggling with quality problems, even though they are committed to quality and work routinely on defect prevention.

Table 9.7: Developments in quality maturity

Statement (*quality maturity level*)	Today* Mean	Ten years ago* Mean	P-values**
We do not know why we have problems with quality (*uncertainty*)	1.67	2.31	0.000
We are asking ourselves if it is absolutely necessary to always have problems with quality (*awakening*)	2.49	2.58	0.444
Through management commitment and quality improvement we are identifying and solving problems (*enlightenment*)	4.33	3.51	0.000
Defect prevention is a routine part of our operations (*wisdom*)	4.38	3.56	0.000
We know why we do not have problems with quality (*certainty*)	3.73	3.34	0.000

* Degree of agreement with statement, both for today and ten years ago, on a 5-point scale from 1=completely disagree to 5=completely agree;
** P-values of the difference between today and ten years ago

9.3.6 Developments in Organisational Performance

Respondents were asked to indicate how a number of performance indicators have developed over the last ten years at their organisations. The results are presented in table 9.8.

Table 9.8 shows that over the past ten years, on average, most of the performance indicators improved somewhat. The major increases occurred in manufacturing flexibility and efficiency; followed by customer satisfaction, plant utilisation and delivery performance. Indicators of inventories such as raw material stocks, work in progress and finished goods inventory have declined somewhat, which means that lean production methods have become more common among these suppliers. The defect rate has, on average, also decreased slightly, although the high standard deviation indicates that there are major differences between the respondents. There are also major differences between the respondents in the development of operating profit, which has on average increased slightly.

Table 9.8: Developments in organisational performance

Performance indicator	Mean*	Standard deviation
Operating profit	3.29	1.38
Customer satisfaction	3.95	0.85
Production volumes	3.85	1.16
Efficiency	4.13	0.88
Manufacturing flexibility	4.19	0.92
Plant utilisation	3.94	1.09
Manufacturing costs	3.62	1.04
Defect rate (Parts Per Million)	2.42	1.21
Delivery performance	3.93	0.85
Raw material stocks	2.52	1.16
Work in progress	2.61	1.17
Finished goods inventory	2.67	1.14
Amount of floor space needed	3.18	1.29

* Extent to which a performance indicator has changed over the last ten years; on a 5-point scale from 1=declined very much to 5=increased very much

Some of the differences in performance between the respondents can be explained from the number of product variants they offer (see figure 9.4). The figure shows on the horizontal axis the operating profit of respondents' organisations, and on the vertical axis their production volumes. In the figure, the respondents' organisations are grouped in five categories on the basis of the extent to which they offer more or less product variety today than ten years ago. The organisations that have increased the number of product variants they offer have higher production volumes and higher operating profit, while the organisations that have reduced the number of product variants they offer have lower production volumes and operating profit. This figure is supported by Pearson correlations between, on the one hand, the five product variety categories and, on the other hand, production volumes (r=0.43, P-value of 0.00) and operating profit (r=0.19, P-value of 0.03).

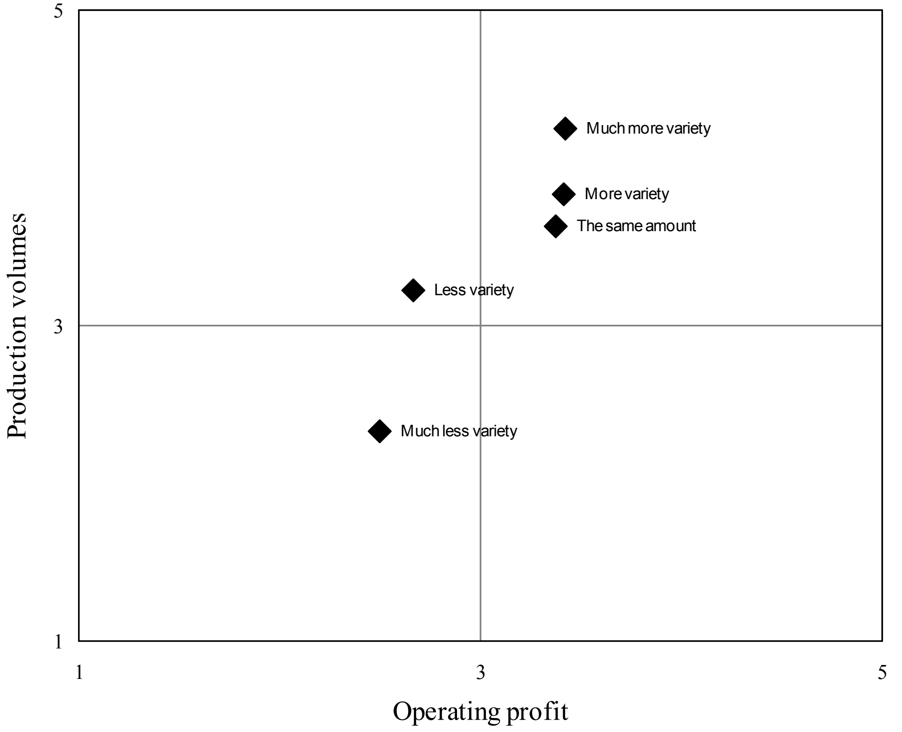


Figure 9.4: Product variety and organisational performance

9.3.7 Application of the Research Model

In terms of the quality control of respondents' organisations, the data support the four levers of Simons' control model. The reliability of the measurement scales for each of the four levers has been tested by means of the Cronbach coefficient alpha (Cronbach, 1951). The alpha scores are all 0.80 or higher (see table 9.9), which indicates that the items for each lever cluster together strongly even though they were presented to the respondents in random order. Nunnally (1978) advocates that measurement scales should have an alpha score of at least 0.60 in order to be acceptable. The outcomes of Cronbach's alpha calculations do not suggest omitting any item from the analyses. Therefore, the items in the questionnaire can be expected to reliably capture the underlying levers of Simons' control model. The second column of table 9.9 indicates the items of question 18 that have been classified under each lever.

Table 9.9: Clusters of questions support the research model

Lever of Simons' control model	Items of question 18	Cronbach's Alpha
Beliefs systems	1, 8, 16, 21, 22, 31	0.86
Interactive control systems	4, 5, 9, 15, 17, 18, 25, 28	0.80
Boundary systems	2, 7, 10, 11, 13, 23, 27, 29, 30	0.83
Diagnostic control systems	3, 6, 12, 14, 19, 20, 24, 26	0.87

The hypothesis of this study is that organisations that have witnessed an increase in product variety or a decrease in product life cycle length are expected to have concentrated more on interactive quality management systems, while organisations that have not witnessed an increase in product variety or a decrease in product life cycle length are expected to focus mainly on diagnostic quality management systems.

This hypothesis has been tested by means of regression analyses. For each lever of Simons' control model a linear regression has been performed against a number of relevant independent variables. Each of these regressions is presented and analysed below.

Interactive Control Systems

The dependent variable in this regression is the relative increase in importance of interactive control systems. This variable is called INTACT and has been derived from the items in the questionnaire that represent interactive control systems, by means of principal components analysis (in order to take the relative importance of each item into account). Independent variables are obviously the relative increase in product life cycle length (LIFECYCLE), and the relative increase in the number of product variants (VARIANTS). Since shortening product life cycles and increasing product variety are likely to occur simultaneously, an interaction term of the two (VAR * LIFE) is included as well. Additional independent variables are:

- The quality maturity (QMATURITY) of the organisation. Before an organisation can consider adapting its quality approach to a changing environment, it should have a minimum quality maturity in the current situation. This variable is derived by means of principal components analysis from the question about Crosby's quality management maturity levels.

- The size (SIZE) of the organisation. Large organisations are more likely to have formal control systems than small organisations.

- The extent to which an organisation is a manufacturing organisation or a service organisation (MANUFACT). This variable is believed to be important because services have always been diverse and they mostly do not have clearly defined life cycles.

The results of the regression are presented in table 9.10. Overall, the model explains 41% of the variance in the dependent variable (INTACT), which is high for research in management. Most coefficients are not significant at a 5% significance level, however, given the small number of observations it is more appropriate to look at the 10% significance level (Verbeek, 2004). LIFECYCLE has a coefficient of -0.861, which means that the importance of interactive control systems decreases when the life cycle length increases. This is in line with the hypothesis because it means that the importance of interactive control systems increases when product life cycles become shorter. The coefficient of VARIANTS, which is -0.173, is also significant at the 10% level. However, the coefficient is negative, which means that the importance of interactive control systems decreases when product variety increases. This is not in line with the hypothesis, since it was hypothesised that the importance of interactive control systems would increase when product variety increases. QMATURITY has a strong and very significant effect on INTACT, which means that organisations that move up the quality maturity ladder will put more emphasis on interactive control systems, all else being equal. The VAR * LIFE interaction term and the size of an organisation do not have a significant effect on the importance of interactive control systems, but the extent to which an organisation is a manufacturing organisation or a service organisation does have a significant influence. The influence of MANUFACT on INTACT is positive, which means that manufacturing organisations make a stronger move towards interactive control systems than service organisations, all else being equal.

Table 9.10: Regression analysis of interactive control systems

Dependent Variable: INTACT

Variable	Coefficient	Std. error	t-statistic	P-values
CONSTANT	-0.125	0.561	-0.222	0.825
LIFECYCLE	-0.861	0.490	-1.758	0.086
VARIANTS	-0.173	0.089	-1.951	0.058
QMATURITY	0.510	0.100	5.078	0.000
SIZE	-0.082	0.092	-0.890	0.378
MANUFACT	0.254	0.109	2.329	0.025
VAR * LIFE	0.173	0.152	1.135	0.263
R-squared	0.410			

Diagnostic Control Systems

The dependent variable in this regression is the relative increase in importance of diagnostic control systems (this variable is called DIAGN and has been derived by means of principal components analysis from the items in the questionnaire that represent diagnostic control systems). The independent variables are identical to the ones used for the regression of interactive control systems.

The results of the regression are presented in table 9.11. The R-squared is 0.694, which means that the model explains nearly 70% of the variance in DIAGN. This is an even higher score than the one found for interactive control systems. However, only one coefficient is significant, which is QMATURITY. Organisations that have, over the last ten years, become more mature in terms of quality management have made more use of diagnostic control systems. The coefficients of LIFECYCLE and VARIANTS are both not significant, which means that we have to reject the hypothesis that developments in product variety and life cycle length have had an influence on the importance of diagnostic control systems.

Table 9.11: Regression analysis of diagnostic control systems

Dependent Variable: DIAGN				
Variable	Coefficient	Std. error	t-statistic	P-values
CONSTANT	0.317	0.477	0.664	0.510
LIFECYCLE	-0.495	0.417	-1.189	0.241
VARIANTS	-0.044	0.076	-0.583	0.563
QMATURITY	0.751	0.085	8.781	0.000
SIZE	-0.050	0.078	-0.639	0.526
MANUFACT	0.001	0.093	0.011	0.991
VAR * LIFE	-0.024	0.128	-0.188	0.852
R-squared	0.694			

Boundary Systems

The dependent variable in this regression is the relative increase in importance of boundary systems (this variable is called BOUND and has been derived by means of principal components analysis from the items in the questionnaire that represent boundary systems). The independent variables are identical to the ones used for the regression of interactive control systems.

The results of the regression in table 9.12 show again a high R-squared (0.569). The variable LIFECYCLE has a significant coefficient of 0.773, which means that the importance of boundary systems decreases when life cycles become shorter. Based on the results of the Small Car Co case (see section 8.5), the opposite effect would have been expected. QMATURITY has again a positive significant influence on the importance of boundary systems, and so do manufacturing organisations.

Table 9.12: Regression analysis of boundary systems

Dependent Variable: BOUND				
Variable	Coefficient	Std. error	t-statistic	P-values
CONSTANT	-0.704	0.576	-1.222	0.229
LIFECYCLE	0.773	0.457	-1.690	0.099
VARIANTS	-0.081	0.085	-0.948	0.349
QMATURITY	0.676	0.097	6.986	0.000
SIZE	-0.053	0.086	-0.615	0.542
MANUFACT	0.271	0.113	2.408	0.021
VAR * LIFE	0.171	0.141	1.212	0.233
R-squared	0.569			

Beliefs Systems

The dependent variable in this regression is the relative increase in importance of beliefs systems (this variable is called BELIEF and has been derived by means of principal components analysis from the items in the questionnaire that represent beliefs systems). The independent variables are identical to the ones used for the regression of interactive control systems.

The results of the regression in table 9.13 show once again a high R-squared (0.616). LIFECYCLE and VARIANTS both have a significant influence on the importance of beliefs systems. When the life cycle length decreases, the importance of beliefs systems increases, and when the number of product variants increases, the importance of beliefs systems decreases. These two effects seem to contradict each other, but they are consistent with the regression of interactive control systems. Like for the other three control systems, QMATURITY has also a significant and positive influence on the importance of beliefs systems.

Table 9.13: Regression analysis of beliefs systems

Dependent Variable: BELIEF				
Variable	Coefficient	Std. error	t-statistic	P-values
CONSTANT	0.528	0.569	0.929	0.358
LIFECYCLE	-0.850	0.496	-1.716	0.093
VARIANTS	-0.173	0.090	-1.923	0.061
QMATURITY	0.785	0.102	7.710	0.000
SIZE	-0.081	0.089	-0.912	0.367
MANUFACT	0.117	0.109	1.069	0.291
VAR * LIFE	0.130	0.153	0.850	0.400
R-squared	0.616			

9.3.8 Effects of Control Systems on Performance

As discussed before, the respondents were asked to indicate the changes that have taken place over the last decade with respect to a list of performance indicators (see section 9.3.6). Since the respondents' organisations have seen different developments with respect to the four levers of Simons' control model, it would be interesting to find any effects this may have had on the performance of these organisations.

To this end, each of the performance indicators has been regressed against the four categories of control systems. However, very few significant effects could be identified. Boundary systems have a negative and significant effect (coefficient of -0.662 and P-value of 0.06) on the defect rate of the organisations, which means that a shift toward boundary systems over the last ten years has reduced the number of defects. Another finding was that diagnostic control systems have a negative and significant effect (coefficient of -0.471 and P-value of 0.01) on customer satisfaction.

9.4 Summary and Conclusions

On the basis of empirical research in the European automotive supply industry, the effects of increasing product variety and shortening product life cycles on the management and improvement of quality have been quantified.

The data have shown that product variety has increased over the last ten years, and product life cycles have become shorter. Moreover, respondents expect these trends to continue in the future. The result has been a more dynamic business environment that is characterised by fast changing customer demand. The suppliers feel that it is critical to respond quickly to these changes. The complexity of the many product variants needs to be taken care of by the suppliers, because car manufacturers are not willing anymore to pay extra for product variety. Consequently, the demands on suppliers are high, and they feel that their abilities to manage quality and costs are now put to the test.

Yet, quality management is essential for suppliers to survive. The importance of quality management has increased over the last decade, and car manufacturers are also paying serious attention to quality. Suppliers feel that car manufacturers find quality equally important as costs and delivery performance.

The survey questionnaire has turned out to be a suitable measure of Simons' control model, because the existence of the four separate levers of the model is strongly supported by the data. Moreover, shifts in terms of the model take place at automotive suppliers, as a result of product variety and product life cycle trends. The regression models for each control lever all have a high R-squared, so the independent variables are able to explain a large part of the variance in each lever.

The regression analyses indicated that the predicted shift towards a more important role for interactive control systems is indeed taking place. However, this effect has only been found for shortening product life cycles and not for increasing product variety. So, the findings about product variety are contrary to the hypotheses. It has not become clear from the data why this is the case, and further research would be of relevance (see comments in chapter 10). In general, changes in product life cycle length over the last ten years have caused more shifts in management control systems than changes in product variety. However interestingly, neither product variety changes, nor product life cycle changes have a significant influence on the use of diagnostic control systems. Therefore, on the basis of this research we must reject the hypothesis that diagnostic control systems will become less important in situations of increasing product variety or shortening product life cycles. A summary of the findings per control lever is presented in table 9.14.

The analyses have made clear that the quality maturity of an organisation has a strong influence on the use of any type of control system. The organisations that have become more mature in their quality management approach make more use of each of the control systems.

Table 9.14: Influence of product variety and life cycles on control systems

	Interactive control systems	Diagnostic control systems	Boundary systems	Beliefs systems
Increasing product variety	Importance decreases	No influence	No influence	Importance decreases
Shortening product life cycles	Importance increases	No influence	Importance decreases	Importance increases

10 Discussion and Conclusions

10.1 Introduction

In this chapter the findings and conclusions of the entire study are presented. The findings section summarises the major findings of this research. The conclusions section reflects on the problem definition and the research questions, and presents the supported and rejected hypotheses. The whole research is then evaluated in terms of contributions to existing literature, the research design, and the research model. The findings and conclusions lead to recommendations for further research, which are outlined in the final section. An afterword hypothesises on a possible third stage of development for quality management.

10.2 Discussion of Findings

This section discusses the major findings of the entire research.

10.2.1 Product Variety and Product Life Cycles

The automotive industry has been chosen as object of this study, based on expectations that this industry is relevant for studying the effects of increasing product variety and shortening product life cycle trends on the management and improvement of quality. With hindsight, this has been a good choice because the two trends are indeed having a strong influence on vehicle manufacturers and their suppliers. During the period of this study, car manufacturers have introduced numerous new car models (see for example Stein, 2005; Kurylko and Rechtin, 2005; Automotive News, 2005a). At the same time, product life cycles have started to decline so rapidly that a year with few new product introductions is expected to lead to significantly lower revenues (see for example Rechtin, 2006b; Automotive News, 2006).

Manufacturing operations at vehicle manufacturers are modified in many ways to cope with the effects of increasing product variety and shortening product life cycle trends. For example, by standardising components between car models, the number of product variants on the assembly line is reduced. Similarly, by making assembly processes suitable for multiple car models, the shortening product life cycles will have a limited influence on the life cycle of the whole process. In general, vehicle manufacturers have adapted methods enabling the customer to perceive that he has a greater choice (more variants and more new product introductions), whilst at one and the same time retaining as much stability as possible for the manufacturer.

To gain an insight into manufacturers' considerations when developing a strategy to cope with increasing product variety and shortening product life cycles, this research has developed a number of scales that help to classify different coping strategies. Both for product variety and for product life cycles, three scales have been developed on the basis of this research (for a detailed description and explanation of the scales, see sections 8.2.2 and 8.2.3). The scales for product variety are:

1. Visible vs. invisible (i.e. is a component visible to the customer?)

2. Functional vs. emotional (i.e. to what extent do customers feel emotionally about certain components?)

3. Potential vs. actual (i.e. to what extent do customers actually choose all the variants that are offered to them?)

The scales for product life cycles are:

1. Customer demand vs. regulation (i.e. the cause of the reduced life cycle length can either be lack of demand or stricter regulations)

2. Core vs. peripheral (i.e. to what extent are changes to the existing model needed?)

3. Product vs. process (i.e. does the end of the product life cycle also mean the end of the process life cycle, or is the process generic enough for multiple car models?)

These novel scales can help researchers to assess the extent to which the two trends of increasing product variety and shortening product life cycles may impact the operations at car manufacturers. By positioning a car component on each of the three product variety scales, it should become clear to what extent the component can be standardised between car models, and to what extent optional components are demanded by customers. Similarly, by positioning individual car models on each of the three scales for product life cycles, it should become clear in what way and to what extent adaptations to car models and processes may be needed.

In a similar way, managers at car manufacturers can make use of the scales for the development of a coherent strategy for offering customers a variety of products, which are replaced on a regular basis.

10.2.2 Changing Quality Controls

The management and improvement of quality by organisations in the automotive industry has developed in several ways. The major findings are discusses below.

Supply Chain Management

The results from the research show a need for change in the way quality is managed in the automotive industry. Car models are updated very frequently and therefore there is no time available to gradually implement improvements. Before the start of the production of a new car model, quality needs to be at a level that was in the past only reached after a considerable period of full production. The car manufacturers are not able anymore to manage this all in-house. So, they have to rely on people who are experts in a certain aspect of a car, and these experts are typically found at the suppliers.

The last decade has seen a significant increase in the outsourcing of production to suppliers. Now the car manufacturers have begun to realise that they also need to outsource management and control processes to their suppliers. It is not sufficient anymore for the car manufacturers to have good quality processes in place in their own organisations because the quality of the final product is to a large extent determined by the suppliers. So, quality management is moving up the supply chain. This development requires different quality systems than quality management inside the own organisation because suppliers are not a part of the hierarchical structure of the car manufacturers. Car manufacturers need to cooperate with suppliers on issues related to design, development and production (Stallkamp, 2005). The importance of supply chain management also has major consequences for sourcing decisions, since selecting suppliers only on the basis of price and product quality can have major consequences if the suppliers have no proper control over their supply chain. Disruptions of supplies mean that the production line will have to be stopped after a short period of time because buffers and stocks will run out quickly since most have been eliminated to reduce costs.

Prevention of Quality Problems

The fact that most buffers and stocks in the whole production chain have gone, means that there is very little time to solve quality problems after they occur. The present study has found that the focus now has to be on preventing problems. As a consequence, the responsibility for quality management has spread all over the organisation and into its supply chain. The quality manager and his department can play a role in curing quality problems through quality inspections, but prevention of quality problems can only be accomplished if everyone in the organisation, and may in the supply chain, manages the quality of his tasks and responsibilities.

Quality Management is Still Important

A clear finding that should not be overlooked is the fact that quality management is still regarded as an important issue. After the business community started to lose interest in Total Quality Management and ISO 9000 series certification (Burgess, 1999; Nwabueze, 2001; Heras et al., 2002), some argued that quality management is not as relevant anymore as it was in the past (Gill and Whittle, 1993; see also Yong and Wilkinson, 1999). However, this research clearly shows that quality management is still seen as an important issue for organisations in the automotive industry. The problem may be that existing quality management research is too much focused on formal systems like ISO 9000 or Six Sigma, and it thereby overlooks the basic quality management systems in place (i.e. systems that enhance customer focus, reduction of variation in organisational processes, and continuous improvement)

Quality Management is Context Dependent

Another finding is that quality management is context dependent. Within the quality management discipline there is a development towards taking the organisational context into account as an important factor that influences quality management systems (Sitkin et al., 1994; Sousa and Voss, 2001). The present study supports the need for taking contextual factors into account, since different contextual settings, in terms of product variety and product life cycles, appear to require different types of quality management systems (see section 10.3.2).

Shop Floor Employees of Key Importance

Despite high-tech equipment and robotics, the shop floor employee is still of key importance to quality performance. The last decade has seen significant developments in high-tech equipment and robotics. Yet, the three case studies and the questionnaire survey clearly indicate that these developments have not reduced the importance of the shop floor employee. On the contrary, the importance of the shop floor employee is currently higher than it was ten years ago. Increased automation has increased the importance of the shop floor employees who work with the robots. While the role of robots is confined to the operational processes, where they are indispensable for checking the quality of the work that employees do, the shop floor employees also play a major role in development, problem solving, and improvement activities. Management no longer works alone on these issues, but cooperates with the shop floor employees.

Hard and Soft Controls

The study also found that hard and soft control systems operate at the same time. Tough contracts are the norm at headquarters level, while good and successful cooperation is no exception at the operational level. Existing literature about management control systems suggests that hard (e.g. fines) and soft control systems (e.g. cooperation) cannot successfully operate at the same time (Arthur, 1994; Truss et al., 1997). The belief is that a person or entity being controlled will not pay attention to soft control systems if there are hard control systems as well. The current study shows that in the automotive industry hard and soft control systems can operate together if they are present at different levels in the organisation. Hard systems are acceptable at corporate levels whereas softer systems encourage cooperation at the individual or work group level.

Product Variety Means Customer Variety

Car manufacturers have increased the number of car models they offer in the market place. As a result, they have attracted a diverse group of customers, who require different things from their cars. It is a challenge for car manufacturers to cope with this development, especially when the differences between customers are related to the more emotional aspects of quality.

10.3 Conclusions

This section briefly discusses the conclusions of the research in terms of the problem definition, research questions and hypotheses.

10.3.1 Problem Definition and Research Questions

The discussions of findings in section 10.2 have, implicitly or explicitly, discussed the conclusions about the problem definition and research questions. Therefore, this section briefly reviews the problem definition and provides an answer to it.

This research is about the quality management discipline. Within this discipline the focus has been on two trends (i.e. increasing product variety and shortening product life cycles) and their influence on quality management systems.

The research had two objectives. The first objective is to understand the influence of increasing product variety and shortening product life cycles on companies, and on the way they manage and improve quality. The second objective is to assess the extent and direction in which quality management systems are changing in situations of increasing product variety and shortening product life cycles. This has led to the following problem definition for this research:

> *How do increasing product variety and shortening product life cycles influence quality management of firms and what is the consequence of this for quality management systems?*

The resulting research questions are:

1. How do increasing product variety and shortening product life cycles affect firms?

2. How do increasing product variety and shortening product life cycles influence quality management of firms?

3. To what extent are quality management systems changing in order to be capable of coping with increasing product variety and shortening product life cycles?

On the basis of the research findings it can be concluded that the answers to each of these questions should be:

1. Increasing product variety and shortening product life cycles affect firms along multiple dimensions, which have been derived from the case studies and discussed in sections 8.2.2 and 8.2.3. This has been discussed in section 10.2.1.

2. Increasing product variety and shortening product life cycles have an influence on many aspects of quality management. These aspects have been discussed in section 10.2.2.

3. The answer to this question is related to the hypotheses which have been derived from the research model. These hypotheses are discussed below in section 10.3.2.

10.3.2 Consideration of Hypotheses

As explained in chapter 3, the four dimensional control model of Simons (see Simons, 1995) has been chosen as research model because it is relevant for both, on the one hand, simple and stable environments and, on the other hand, complex and unpredictable environments. According to the model, these types of environments both require a different combination of the four types of control systems. Organisations that operate in simple and stable environments can focus mainly on the diagnostic type of control systems, whereas organisations in complex and unpredictable environments will have to make more use of the interactive type of control systems in order to be successful (see chapter 3).

As argued in chapter 1, increasing product variety and shortening product life cycles both mean that the environment becomes more complex and unpredictable. Therefore, the extent to which and organisation is influenced by increasing product variety and shortening product life cycles is expected to be reflected in the extent to which the organisation makes use of the different types of control systems.

On the basis of the research model, in combination with the anticipated influence of product variety and product life cycle trends on the case companies (see table 4.2), a number of hypotheses were formulated (see table 4.3). The hypothesised effects on quality management systems for the case companies are repeated in table 10.1.

Table 10.1: Hypotheses about quality management systems for the cases

Case company	Hypotheses
Heavy Truck Co	Quality management is mainly focused on diagnostic systems.
Small Car Co	The quality management focus has shifted towards interactive systems.
Premium Car Co	The quality management focus has shifted towards interactive systems.

As explained in section 4.5.2, the hypotheses for the questionnaire survey were in line with the case hypotheses. So, organisations that have witnessed an increase in product variety or a decrease in product life cycle length were expected to have concentrated more on interactive quality management systems, while organisations that have not witnessed an increase in product variety or a decrease in product life cycle length were expected to focus mainly on diagnostic quality management systems.

The findings from the case studies support to some extent the hypotheses:

- The hypothesis about Heavy Truck Co is supported. Diagnostic quality management systems are sufficient for this organisation which experiences a limited influence of product variety and life cycle trends.

- The hypothesis about Small Car Co is supported. For this organisation, which operates in a situation of shortening product life cycles, it is not sufficient anymore to rely on diagnostic quality management systems. Instead, it is necessary to approach quality management in an interactive way, although within strict and clear boundaries.

- The hypothesis about Premium Car Co is not supported. For this organisation, which operates in a situation of increasing product variety, there appears to be no need to concentrate on interactive control systems, because its quality management systems have remained a mix of all four types of control systems. However, focusing only on diagnostic control systems also does not seem to be a good strategy. Still, this is an indication that increasing product variety may have a different influence on quality management systems than product life cycles.

The statistical analyses of the automotive supplier data indicated that the predicted shift towards a more important role for interactive control systems is indeed taking place. However, this effect has only been found for shortening product life cycles and not for increasing product variety. So, the findings about product variety are contrary to the hypotheses. It has not become clear from the data why this is the case, and further research would be of relevance (see section 10.5). In general, changes in product life cycle length over the last ten years have caused more shifts in management control systems than changes in product variety. Neither product variety changes, nor product life cycle changes have a significant influence on the use of diagnostic control systems. Therefore, on the basis of the questionnaire survey we must reject the hypothesis that diagnostic control systems will become less important in situations of increasing product variety or shortening product life cycles.

Summarising, the support for the hypotheses is mixed. Shortening product life cycles appears indeed to lead to a stronger focus on interactive control systems, while increasing product variety does not. A possible explanation for this finding is presented in section 10.3.3 below. The use of diagnostic control systems appears to be unrelated to the trends of shortening product life cycles and increasing product variety. Only in the cases studies some developments in the use of diagnostic control systems have been found, while the questionnaire survey indicated no developments that can be attributed to the product variety and life cycle trends. An explanation for this finding may be the strict use of formal quality management systems in the automotive industry, which are, particularly for suppliers, a prerequisite to do business in this industry. These formal quality management systems are predominantly of a diagnostic nature (e.g. measurements on products and processes, maintaining records for traceability, and reviewing training requirements for employees) and need to be complied with, regardless of the specifics of the product and the organisation. Therefore, organisations in the automotive industry do not have the option to reduce their efforts in terms of formal quality management systems when these systems have become less suitable for the changed market environment in which these organisations operate.

10.3.3 Product Variety vs. Product Life Cycles

As pointed out in 10.2.1, the principle used to cope with both increasing product variety and shortening product life cycles is the same. This principle is to increase customer perception of increased variety and of increased new product flow whilst preserving stability as far as possible for the manufacturer. So, variety is increased for the customer only in the visible and not in the invisible areas and, similarly, it is concentrated in the functional areas rather than in those which might elicit an emotional response. Car manufacturers are careful to appear to offer a number of variants but this spread of possible variants can be made manageable either because it is predictable that few customers, if any, will ever choose them or because dealers and salesmen can be instructed and incentivised to only offer a limited number of variants.

A similar situation may emerge as a reaction to customer demands for new products and the resulting reduction of product life cycle length. Again, the aim is to have the customer perceive that new products are continually being offered and yet for the manufacturer to keep a high element of stability in his operation. This is achieved through, for example, changing peripheral rather than core components of the product and changing the product rather than the process used to manufacture it. This would all result in increasing innovation in the customers' eyes, but still allow the manufacturer a degree of stability.

These two organisational situations of increasing product variety and decreasing product life cycles differ in their degree of uncertainty. Looking back on the case study interviews, we would suggest that managing increases in perceived product variety has a higher degree of predictability than managing the effects of decreasing product life cycles.

The changes required to manage increasing product variety can be planned, once the trend has been identified. Therefore, increasing product variety can be relatively easily accomplished. For example, the variety of various visible components offered by Premium Car Co can fairly quickly be altered if the market demand so requires. The interviewees told us that changes in this respect were constantly being introduced. So, increasing product variety is relatively easy to do and can be carried out relatively fast. It may involve interacting with suppliers but it is not complex or difficult and can be quickly introduced.

In contrast, managing a situation in which product life cycles are shortening has much higher elements of uncertainty and unpredictability. Changes in product life cycles are more uncertain since they are dependent upon factors like fashion, other companies' technological advances and of moves which other parties (such as competitors) make, all of which are difficult to predict. Not only are the changes unpredictable but when they occur, the interviewees told, there is great time pressure. For example, Premium Car Co's product sales are now falling unexpectedly fast and a new replacement model has to be developed much quicker than was either planned or expected. Developing new products in the automotive industry is very time consuming and complicated. It can only be achieved through close cooperation across all relevant functions and parts of the supply chain. Such close cooperation under time pressure and in a situation where hierarchical power is absent, will need more interactive type of control systems.

The literature suggests that increasing uncertainty leads to the use of more interactive control systems (Chenhall, 1993; Simons, 1995). As a result of our research we would suggest that uncertainty is too general a term because it has many dimensions. Both increasing product variety and shortening product life cycles are subject to uncertainty since they require working through outsourcing with suppliers in a relative power vacuum. The difference between the two situations lies in the complexity of the task and in the time pressure involved. Increasing product variety can be relatively quickly and easily accomplished. Introducing new products is much more complicated and time consuming, and its unpredictability brings with it much greater time pressure.

In our study, the dimension of uncertainty that is related to increased use of interactive control systems seems thus to be a combination of complexity and time pressure. Under these circumstances, it is hardly surprising that goals can only be achieved as a result of close cooperation both across all the relevant functions and indeed organisations involved. Simple reliance on top down implemented diagnostic controls is hardly likely on its own to be successful in such a dynamic and complex situation.

Our study suggests that it is only in some kinds of uncertain situations (those involving complex problems requiring a variety of participants and under high time stress) that there will be a need for increased use of interactive control systems.

10.4 Evaluation of the Research

This section discusses the contributions of the research to existing literature. In addition, it indicates the limitations of the research and it evaluates the research design, which leads on to some comments on Simons' control model.

10.4.1 Contributions of this Study

This study has taken a novel approach to quality management, since it has made use of a model that has not been used before in this area. Simons' control model has turned out to be applicable to quality management research. The translation into automotive industry practices has been successful as well (although section 10.4.3 will outline some problems and limitations). Moreover, the analyses of the case studies and the questionnaire survey have led to concrete results. This research has developed a measure of the four dimensions of Simons' model, which appears to be a contribution to the literature since we have not been able to discover any previous studies that have made an attempt at quantifying this model.

The analysis of quality management systems by means of Simons' control model has helped to look at quality management from a different perspective. The model makes it possible to take strategic aspects and characteristics of the business environment into account when assessing an organisation's quality management systems. As such it helps researchers to make the switch from a universalistic approach to quality management, towards a context dependent approach.

On the basis of the research two sets of scales have been developed, which help to classify strategies for product variety and product life cycles (see section 10.2.1). These scales may help both academic researchers, as well as practitioners in the automotive industry.

Another contribution of this research is the finding that in the automotive industry hard and soft controls operate at the same time. This finding has been explained in section 10.2.2.

10.4.2 Research Methodology Critique

In this section the limitations of the study are pointed out and the research design is evaluated.

Limitations of the Research

Obviously, the findings of this research should be considered within certain boundaries. Both the case studies, as well as the questionnaire survey have been used to learn and understand developments that have taken place over a relatively long period of time. Over this period of time, the automotive industry has seen developments that have influenced the way manufacturers and suppliers manage their business. Two of these developments have been increasing product variety and shortening product life cycles. However, there have, of course, been many more developments. The research has attempted to single out the effects of increasing product variety and shortening product life cycles, but, as anticipated, this has not always been clear.

The research has studied three Western European case companies and their suppliers, and a sample of Western European automotive suppliers. Therefore, the findings need not be universally valid for the global automotive industry. Another limitation is the generalisability of the findings to different industry sectors. Since the study has focused on the automotive industry, it is hard to tell if other industries have witnessed similar developments. As indicated in chapter 1, other industries are also experiencing the effects of increasing product variety and shortening product life cycles, and it is expected that many other industries will follow suit. Pine (1993, p. 208) argued:

> *"There are few products more complex than automobiles, and few processes more complex than automobile manufacture. If automobiles can be mass-customized ... most any product or service can also be mass customized."*

Industry sectors that (will) experience the same developments as the automotive industry has experienced over the last decade, may benefit from studying the way the automotive industry has dealt with the challenges. As such the findings from this research may benefit other industries.

Evaluation of Research Design

The research design, which consisted of case studies and a questionnaire survey, has turned out to be a suitable approach for the research. The case studies have uncovered the underlying dimensions of the problems, and have indicated how the effects of increasing product variety and shortening product life cycles have an influence in the automotive industry. This has been essential to the research because car manufacturing is a complex business, which is difficult to comprehend from books and articles. By studying assembly lines from start to finish and by talking to the many people involved, the true magnitude and complexity of car manufacturing becomes clear. A questionnaire survey alone would never be able to capture the scale of the challenges that car manufacturers and their suppliers are faced with.

However, after the case studies, a follow up questionnaire survey proved to be useful. The case studies had still left some questions unanswered, which could be focused on by means of the questionnaire survey. For example, the ambiguous results from the case studies about the effects of increasing product variety could be tested out by means of the questionnaire survey. The fact that the questionnaire survey provided clear results about the influence of product variety on quality management, was an important contribution to the overall findings.

10.4.3 Simons' Control Model: Some Observations

Simons' four levers of control systems (Simons, 1995) has proved to be useful for studying developments in quality management systems as a result of changes in the strategy and environment of organisations. In the first place, the model has been used successfully in the quality management field, although it has been developed from a management control perspective. Secondly, the model could be used as the basis for a questionnaire survey, and the resulting data supports the existence of the four different dimensions of the model.

However, the application of the model has also raised some difficulties. The first problem is that nearly every business aspect can be defined as a control issue. Therefore, it is important to adopt clear criteria for the selection of the business issues that will be incorporated in the model. In the current study, a team of academic experts have, in cooperation with the interviewed managers, selected the business aspects that would be incorporated in the model.

Another problem with the model is the fact that the time dimension is not explicitly taken into account. The model predicts that different strategies and environments require a different mix of control systems. However, the model does not discuss the effects on the control systems of an organisation which changes its strategy or which operates in a changing environment (see also Ramos and Hidalgo, 2003). The current study has found that the importance and magnitude of a shift from one control lever to the other can be significant for an organisation.

A final problem with the model is the fact that the classification of systems into the four categories can be difficult. For example, the category to which a control system belongs can differ, dependent on whether the focus is on planning for the control system or on the operational control system itself. A control system that stimulates discussion and interaction may in practice be an interactive control system, while the initiation of the system may have been implemented in a strict top-down fashion because the management requires employees to cooperate with each other (i.e. as a boundary system).

10.5 Recommendations for Further Research

The research has generated a number of issues in relation to quality management that require further research. The issues are discussed below.

Context Dependency of Quality Management

The influence of contextual factors on the management and improvement of quality is clearly an important issue for research. However, further research needs to be undertaken to understand what influence different contextual factors have on quality management.

This study had hypothesised that increasing product variety and shortening product life cycles both increase complexity and unpredictability. As such, they were both expected to stimulate organisations to use more interactive control systems. However, the results of the analyses show that this only goes for shortening product life cycles. To understand why shortening product life cycles leads to more emphasis on interactive control systems, while an increasing product variety leads to less emphasis on interactive control systems, more needs to be known about the specific effects that these two trends have in terms of complexity and unpredictability. An important extension of the current study would therefore be an in-depth study into the effects of increasing product variety on quality management systems.

Simons' Control Model

The application of a management control model to quality management has suggested that quality management can, and should, move away from the universalistic approach towards a contingency approach. Moreover, the model has been useful in determining what changes are needed. Therefore, further research on the Simons' model in relation to the context dependency of quality management may lead to interesting results.

The type of organisational context in terms of Simons' model can help to explain the success or failure of widely used quality management systems (e.g. ISO 9000). The application of the ISO 9000 series of quality systems standards has lead to mixed results (Capon et al., 1990; Rust et al., 1994; Flynn et al., 1995; Terziovski et al., 1997; Chow-Chua et al., 2003; Terziovski et al., 2003). The approach taken in the current study can help to explain why this is the case, because the ISO 9000 systems are predominantly diagnostic systems and as such they may be unsuccessful when applied to organisations that require interactive systems.

Quality is Redefined

Quality is about satisfying if not delighting the customer. But what the customer sees as quality is being redefined. The rise of brands and of marketing aimed at turning ownership into an emotional or social experience (see for example Pine and Gilmore, 1999) has led many customers to complain if their feelings after purchase do not fit with what they have been led to expect. Quality can trace and improve technical functional faults. How can they also trace and improve a customer's disappointing emotional purchasing experience? Classical quality control was about having technical specifications and then manufacturing according to these specifications. It was then a matter of collecting information on defects and deciding to act on them or not. Currently, quality control is not only about technical specifications but also about emotional specifications. The emotional quality problems are much harder to manage than the technical ones and cannot be solved just by means of diagnostic control systems. Here lies an important area for further research.

Even when quality management is confined to the technical issues, much is about to change within the quality discipline. The research suggests that the quality of the finished product is not the standard anymore, instead manufacturers should focus on operational quality and design for disassembly (to comply with environmental legislation). Operational quality and design for disassembly are highly dependent on the way the customer uses a vehicle, which is something the manufacturer has little influence on. The Heavy Truck Co case has shown some examples of these. Metal door handles are replaced with plastic ones because the plastic one will last long enough and is easier to recycle. However, this technical life span of the door handle depends on how often the handle is used and how it is treated. How can manufacturers predict this? Another example is the hydraulic cab tilt system, which is designed to last a number of operations and no more. However, some corporate customers require their drivers/operators to tilt the cab and check the engine every morning, while others will only do it for servicing. Hence, it is essential to know what the required number of operations is that the system should perform over a period of time.

Influence of Suppliers on Quality

One of the major findings of this research is the extent to which suppliers influence the quality of the end product. This is certainly an area in which more research is needed. Suppliers are not under direct control of their corporate customers, and therefore, these corporate customers cannot use control systems that have been designed for hierarchical organisations. Moreover, the success with which corporate customers can control their suppliers is dependent on the extent to which their quality cultures are in line. Corporate customers have to deal with many suppliers, each one having its specific quality culture, yet they all work on the same end product.

Influence of Shop Floor Employees on Quality

Current manufacturing technology is very advanced and capable of completing many tasks without human interference. However, this research has found that the importance of the shop floor employees has only increased over the last decade. These two developments seem to be at odds with each other. It would be interesting to gain an insight into the extent to which shop floor employees are able to influence the quality of the end product in today's highly automated production processes.

Role of Quality Maturity

Quality maturity as a concept has been known for a relatively long time (see Crosby, 1979), however, its importance in current quality management research may be overlooked. The analyses of the present study have made clear that the quality maturity of an organisation has a strong influence on the use of quality control systems. Therefore, quality management research would benefit from paying explicit attention to the quality maturity of the studied organisations.

Different Organisations Require Different Models

The demand for many different product variants is an indication that customers value different aspects of the products they buy. This requires organisations to fulfil the demands of the customers who are relevant to the organisations. Therefore, the quality models used should be in line with the strategy of the organisation. Universal models to assess quality are not appropriate because they do not sufficiently take into account the differences between organisations and brands within organisations. In the automotive industry, the need for customised quality models is becoming clear. Managers of General Motors' Hummer brand realised that their cars ranked poorly in the industry leading J.D. Power surveys because of, among other things, their high fuel consumption (Jewett, 2005). However, Hummer's customers value the large and heavy appearance of their cars, which they do not want to trade in for lower fuel consumption.

Common Car Components

According to the literature, modules in automotive assembly were intended to work like Lego pieces, which can be connected in many different ways and result in an unlimited number of creations (Oude Weernink, 2006b). In the practice of the case companies, modular sourcing is not very much like that. Components are grouped together in modules, but most of the time these modules are only suitable for single car models. Moreover, high variety is not achieved by combining different modules, but by changing the module itself. When car manufacturers talk about commonising car parts, they usually mean that they use the same battery. Apparently, first tier module suppliers carry the responsibility to use common parts for different modules. However, many first tier suppliers operate plants in supplier parks next to the car manufacturers. These plants are usually dedicated to the car manufacturer only. It is questionable to what extent these plants cooperate by making use of common components. Further research into this would help to explain the extent to which common parts are used in the automotive industry.

10.6 Epilogue: a Possible Third Stage of Development for Quality Management?

The research has shown that car manufacturers and their suppliers currently have to deal with three major kinds of problems:

1. Problems whose causes might be technically simple, but whose traceability is complicated and costly. A good example here would be the traceability and time issues caused by the combination of increased outsourcing, modular design, and long supply chains.

2. Problems which are technically difficult. For example, our interviewees told us that software quality problems are very difficult to solve. The complexity of the many lines of programming code in modern cars makes it very difficult to pinpoint the cause of software quality problems. Yet, even in mass market cars, the amount of software in vehicles is increasing rapidly (Sherefkin and LaReau, 2006; Huhn and Schaper, 2006).

3. Problems which are not caused by technical defects. An example of these are the more emotional quality dimensions that are becoming more important to many customers. Because of the trend to produce a global vehicle that must serve many different markets (see for example Lapham, 2005; Hamprecht and Kranz, 2006; Treece, 2006b), in combination with the growing importance of emotional quality issues, the likelihood of one cultural group of customers being dissatisfied whilst others are quite happy has increased.

These three kinds of quality problems taken together could well mean that a new era of quality management has been born. As pointed out in this thesis, quality was first concerned with cure (i.e. curing bad quality). As technology and markets developed, there was less and less time and money for successful cure, and so quality moved into the preventive mode. Now, again as a result of shifting technology and markets, our interviewees were suggesting that maybe quality is entering a third phase: the phase of coping with failure.

The aforementioned increasing complexity involved in preventing and curing quality is bound to increase the likelihood that customers will experience faults, and complaints will arise. Some of these will be serious enough to warrant a product recall. We have already pointed out that recalls have been clearly increasing over the last few years (Simon, 2004).

Quality management research has always, in the past, regarded bad quality as being solvable, and even being free (Crosby, 1979). Tools and techniques have been developed to solve and then to prevent bad quality from occurring. Now, with a new series of nearly intractable problems being thrown up by both technological and market changes, the quality management discipline has to face the fact that maybe some of the problems are neither preventable nor curable.

Quality management research has to devise tools and techniques to enable the customer and the organisation to deal with these new quality issues.

If rapid introduction of totally new car models, using long complicated supply chains, will involve teething troubles; if increasing software in cars is bound to lead to some glitches sooner or later; if global marketing of the same vehicle is bound to lead to differing emotional reactions amongst customers; then the quality management discipline needs to devise methods of ensuring that despite all this, the customer remains satisfied and loyal. All car manufacturers will be hit by these issues, and such problems will soon be (and must be) seen by customers as normal. Therefore, for the future, it will become important to devise rapid cheap product recall and replacement procedures, and attractive compensation packages for customers involved. The brand image in the market place, despite the glitches, has to be maintained.

Only one of the originally four companies whom we approached to take part in this research, declined. They were approached in the correct manner, using trusted intermediaries to vouch for our credibility and trustworthiness. The company took much longer to deliberate than the other three companies, presumably looking carefully at our previous research work. Finally, we were told that unfortunately our research would take place at too inconvenient a time for them. The company was Toyota. Only later did we realise that our request to visit them to learn more about how they are still managing quality successfully, despite being subject to the effects of increasing product variety and shortening product life cycles, would have taken place just at the time the company was having to manage its largest ever product recall (Automotive News, 2005b; Stoffer, 2006). Japanese companies have a record of allowing Westerners to look and learn about anything that they do not regard as being of strategic importance or which they do not believe Westerners capable of copying successfully. Maybe Toyota now believes, as our research would tentatively suggest, that some quality failures are now inevitable, and that therefore it is now of strategic importance how quality failure is managed.

That failure can earn a company a top reputation has been shown before by Toyota's premium brand Lexus. In 1987, when the Lexus brand was introduced in the USA, it had no premium status at all, and just a few months after the introduction a defect in the cruise control showed up with two cars (Denove and Power, 2006). Lexus decided to voluntarily recall every car it had sold and fix the defect, which might have hurt the brand very much. However, Lexus managed the defect in an unusual way (Denove and Power, 2006):

“When Lexus owners received their recall notices, they were in for a surprise. The notices not only included a detailed apology letter, but owners were advised that their dealer would come to their homes, pick up the car, and leave them a loaner car free of charge while the repair was made. Every car was returned to the owner washed, detailed, and with a full tank of gas. There was even a gift sitting on the driver's seat as thanks for their patience.

And when a customer lived beyond the normal range of a Lexus dealership, the company's field personnel took it upon themselves to drive to the home, break out their tools, and fix the problem right there in the customer's own garage. In at least one case this meant getting on a plane and flying a technician to Alaska to fix a customer's car, because Lexus didn't yet have any dealers outside the continental United States.

For all practical purposes, we believe this recall marked the day that Lexus was truly born, and not the day it sold its first car. This is because the recall was the day that Lexus showed the world what it really meant to be customer-focused.”

This example shows that it is not the failure itself that makes the difference, but the way organisations cope with failure. This ability to cope with failure may become an increasingly important issue in the future of quality management.

References

Agrawal, M., T.V. Kumaresh and G.A. Mercer (2001), "The false promise of mass customization", *The McKinsey Quarterly*, No. 3, pp. 62-71.

Aldred, C. and B. Wernle (2004), "Suppliers face rising risk without recall insurance", *Automotive News*, 31 May. http://www.autonews.com/article.cms?articleId=48457

Alford, D., P. Sackett and G. Nelder (2000), "Mass customisation – an automotive perspective", *International Journal of Production Economics*, Vol. 65 No. 1, pp. 99-110.

Anderson, J.C., M. Rungtusanatham and R.G. Schroeder (1994), "A Theory of Quality Management Underlying the Deming Management Method", *The Academy of Management Review*, Vol. 19 No. 3, pp. 472-509.

Anthony, R.N. (1965), *Planning and Control Systems: a Framework for Analysis*, Division of Research, Harvard Business School, Boston.

Anthony, R.N. (1988), *The Management Control Function*, Harvard Business School Press, Boston.

Antony, J. and T. Taner (2003), "A conceptual framework for the effective implementation of statistical process control", *Business Process Management Journal*, Vol. 9 No. 4, pp. 473-489.

Arrow, K.J. (1964), "Control in Large Organizations", *Management Science*, Vol. 10 No. 3, pp. 397-408.

Arthur, J.B. (1994), "Effects of Human Resource Systems on Manufacturing Performance and Turnover", *The Academy of Management Journal*, Vol. 37 No. 3, pp. 670-687.

A.T. Kearney (1994), “Survive the Vortex: Focus on the Customer”, *Managing Service Quality*, Vol. 4 No. 1, pp. 6-10.

Automotive News (2002), “Hubbert: Mercedes has niches to conquer”, 11 March. http://www.autonews.com/article.cms?articleId=38610

Automotive News (2004), “Guide to vehicle assembly plants in Europe”, 29 November. http://www.autonews.com/assets/PDF/CA25411020.PDF

Automotive News (2005a), “Nissan sees 3.65 million annual vehicle sales by September”, *Automotive News*, 22 September. http://www.autonews.com/apps/pbcs.dll/article?AID=/20050922/REG/509220709.

Automotive News (2005b), “Toyota to recall record 1.4 million cars globally”, *Automotive News*, 18 October. http://www.autonews.com/apps/pbcs.dll/article?AID=/20051018/REG/510180714.

Automotive News (2006), “Nissan fourth quarter operating profit down”, *Automotive News*, 25 April. http://www.autonews.com/apps/pbcs.dll/article?AID=/20060425/REUTERS/60425003.

Avishai, B. and W. Taylor (1989), “Customers Drive a Technology-Driven Company: An Interview with George Fisher”, *Harvard Business Review*, Vol. 67 No. 6, November/December, pp. 106-114.

Baldwin, C.Y. and K.B. Clark (1997), “Managing in an Age of Modularity”, *Harvard Business Review*, Vol 75 No 5, pp. 84-93.

Barksdale, H.C. and C.E. Harris (1982), “Portfolio Analysis and the Product Life Cycle”, *Long Range Planning*, Vol. 15 No. 6, pp. 74-83.

Bates, H., M. Holweg, M. Lewis and N. Oliver (2004), “Motor vehicle safety recalls: trends, patterns and emerging issues”, in: Van Wassenhove, L.N., A. de Meyer, E. Yücesan, E.D. Günes and L. Muyldermans (eds.) *Operations management as a change agent, vol. 2, 11th International Annual EurOMA Conference*, 27-30 June, INSEAD, Fontainebleau, France, pp. 73-82.

Behara, R.S. and D.E. Gundersen (2001), "Analysis of quality management practices in services", *International Journal of Quality & Reliability Management*, Vol. 18 No. 6, pp. 584-603.

Bell, G.D. (1965), "The Influence of Technological Components of Work Upon Management Control", *Academy of Management Journal*, Vol. 8 No. 2, pp. 127-132.

Bhote, K.R. and A.K. Bhote (1991), *World-Class Quality: Using Design of Experiments to Make it Happen (Second Edition)*, American Management Association, New York.

Bhuiyan, N. and A. Baghel (2005), "An overview of continuous improvement: from the past to the present", *Management Decision*, Vol. 43 No. 5, pp. 761-771.

Bisbe, J. and D. Otley (2004), "The effects of the interactive use of management control systems on product innovation", *Accounting, Organizations and Society*, Vol. 29 No. 8, pp. 709-737.

Bisgaard, S. and J. de Mast (2006), "After Six Sigma – What's Next?", *Quality Progress*, January, pp. 30-36.

Boynton, A.C. and B. Victor (1991), "Beyond Flexibility: Building and Managing the Dynamically Stable Organization", *California Management Review*, Vol. 34 No. 1, pp. 53-66.

Bruining, H., M. Bonnet and M. Wright (2004), "Management control systems and strategy change in buyouts" *Management Accounting Research*, Vol. 15 No. 2, pp. 155-177.

Bryce, G.R. (1991), "Quality Management Theories and Their Application", *Quality*, January, pp. 15-18.

Burgess, N. (1999), "Standards and TQM at the opening of the twenty-first century", *The TQM Magazine*, Vol. 11 No. 6, pp. 456-460.

Caffyn, S. (1999), "Development of a continuous improvement self-assessment tool", *International Journal of Operations and Production Management*, Vol. 19 No. 11, pp. 1138-1153.

Campanella, J. (1999), *Principles of Quality Costs: Principles, Implementation and Use (Third Edition)*, ASQ Quality Press, Milwaukee, Wisconsin.

Capon, N., J.U. Farley and S. Hoening (1990), "Determinates of financial performance: a meta analysis", *Management Science*, Vol. 36 No. 10, pp. 1143-1159.

Chappell, L. (2005), "Quality risks increase as microprocessors multiply, Does it really take 3 control units to operate a window?", *Automotive News*, 11 April. http://www.autonews.com/article.cms?articleId=52526

Chenhall, R.H. (2003), "Management control systems design within its organizational context: findings from contingency-based research and directions for the future", *Accounting, Organizations and Society*, Vol. 28 No. 2/3, pp. 127-168.

Chenhall, R.H. and D. Morris (1986), "The Impact of Structure, Environment, and Interdependence on the Perceived Usefulness of Management Accounting Systems", *The Accounting Review*, Vol. 61 No. 1, pp. 16-35.

Chow-Chua, C., M. Goh and T.B. Wan (2003), "Does ISO 9000 certification improve business performance?", *International Journal of Quality and Reliability Management*, Vol. 20 No. 8, pp. 936-953.

Cole, R.E. (1999), *Managing Quality Fads: How American Business Learned to Play the Quality Game*, Oxford University Press, New York.

Connelly, M. and R. Sherefkin (2005), "Chrysler rewards top vendors, Plan offers early involvement in design process", *Automotive News*, 24 January. http://www.autonews.com/apps/pbcs.dll/article?AID=/20050124/SUB/501240834.

Cox, G. (1997), "Customer focus – a commercial imperative", *Managing Service Quality*, Vol. 7 No. 1, pp. 27-30.

Cox, J. and B.G. Dale (2001), "Service quality and e-commerce: an exploratory analysis", *Managing Service Quality*, Vol. 11 No. 2, pp. 121-131.

Creswell, J.W. (1994), *Research Design: Qualitative and Quantitative Approaches*, Sage Publications, Thousand Oaks.

Creveling, C.M., J.L. Slutsky and D. Antis Jr. (2002), *Design for Six Sigma: in Technology and Product Development*, Prentice Hall PTR, Upper Saddle River, New Jersey.

Cronbach, L.J. (1951), “Coefficient alpha and the internal structure of tests”, *Psychometrika*, Vol. 16 No. 3, pp. 297-334.

Crosby, P.B. (1979), *Quality Is Free: The Art of Making Quality Certain*, McGraw-Hill, New York.

Da Silveira, G., D. Borenstein and F.S. Fogliatto (2001), “Mass customisation: Literature review and research directions,” *International Journal of Production Economics*, Vol. 72 No. 1, pp. 1-13.

Dale, B.G. (2003), *Managing Quality (Fourth edition)*, Blackwell Publishing, Oxford.

Dale, B.G. and J.J. Plunkett (1999), *Quality Costing (Third Edition)*, Gower Publishing, Aldershot, Hampshire.

Dale, B.G., P.Y.-Wu, M. Zairi, A.R.T. Williams and A. van der Wiele (2001), “Total quality management and theory: An exploratory study of contribution”, *Total Quality Management*, Vol. 12 No. 4, pp. 439-449.

Dale, B.G., M. Zairi, A. van der Wiele and A.R.T. Williams (2000), “Quality is dead in Europe – Long live excellence, True or false?”, *Measuring Business Excellence*, Vol. 4 No. 3, pp. 4-10.

Davila, T. (2000), “An Empirical Study on the Drivers of Management Control Systems’ Design in New Product Development”, *Accounting, Organization and Society*, Vol. 25 No. 4/5, pp. 383-409.

De Saint-Seine, S. (2004), “PSA tells suppliers to make better parts, Automaker gives its vendors 3 years to fix parts quality”, *Automotive News Europe*, 13 December. http://europe.autonews.com/article.cms?articleId=55306

De Saint-Seine, S. (2006), “PSA is getting better parts, French rival Renault also claims big boost in component quality”, *Automotive News Europe*, 23 January. http://www.autonews.com/apps/pbcs.dll/article?AID=200660120074

Dean, J.W. and D.E. Bowen (1994), “Management theory and total quality: Improving research and practice through theory development,” *The Academy of Management Review*, Vol. 19 No. 3, pp. 392-418.

Deming, W.E. (1982), *Quality, Productivity, and Competitive Position*, MIT Center for Advanced Engineering Study, Cambridge, Massachusetts.

Deming, W.A. (1986), *Out of the Crisis*, Cambridge University Press, Cambridge.

Denove, C. and J.D. Power (2006), Satisfaction: How Every Great Company Listens to the Voice of the Customer, Penguin Group, New York.

Ditillo, A. (2004), “Dealing with Uncertainty in Knowledge-Intensive Firms: the Role of Management Control Systems as Knowledge Integration Mechanisms”, *Accounting, Organization and Society*, Vol. 29 No. 3/4, pp. 401-421.

Easterby-Smith, M., R. Thorpe and A. Lowe (2002), *Management Research: An Introduction (Second Edition)*, Sage, London.

Feigenbaum, A.V. (1986), *Total Quality Control (Third Edition)*, McGraw-Hill, New York.

Feldman, D.C. (2004), “What are We Talking About When We Talk About Theory?”, *Journal of Management*, Vol. 30 No. 5, pp. 565-567.

Fisher, M., K. Ramdas and K. Ulrich (1999), “Component Sharing in the Management of Product Variety: A Study of Automotive Braking Systems”, *Management Science*, Vol 45 No 3, pp. 297-315.

Flynn, B.B., R.G. Schroeder and S. Sakakibara (1995), “The impact of quality management practices on performance and competitive advantage”, *Decision Sciences*, Vol. 26 No. 5, pp. 659-692.

Ford, H. (1926), *Today and Tomorrow*, William Heinemann Ltd., London.

Foxall, G. and R.E. Goldsmith (1994), *Consumer Psychology for Marketing*, Routledge, London.

Frazier, G.L., R.E. Spekman and C.R. O'Neal (1988), "Just-In-Time Exchange Relationships in Industrial Markets", *Journal of Marketing*, Vol 52 No 4, pp. 52-67.

Frink, L. (2006), "Road rage, Infrastructure woes plague growing region", *Automotive News*, 6 March. http://www.autonews.com/apps/pbcs.dll/article?AID=/20060306/FREE/60303095

Garvin, D.A. (1988), *Managing Quality, The Strategic and Competitive Edge*, The Free Press, New York.

Garvin, D.A. (2000), *Learning in Action, A guide to putting the learning organization to work*, Harvard Business School Press, Boston.

Giglioni, G.B. and A.G. Bedeian (1974), "A Conspectus of Management Control Theory: 1900-1972", *Academy of Management Journal*, Vol. 17 No. 2, pp. 292-305.

Gill, J. and S. Whittle (1993), "Management by Panacea: Accounting for Transience", *Journal of Management Studies*, Vol. 30 No. 2, pp. 281-295.

Graham, A. (2005), "New faces to affect component purchasing in Europe", *Automotive News Europe*, 21 February. http://europe.autonews.com/article.cms?articleId=55516

Hall, R.W. (1983), *Zero Inventories*, Dow Jones-Irwin, Homewood, Illinois.

Hamprecht, H. and R. Kranz (2006), "GM plans to replace Saturn Ion with Opel car, Rebadged Astras will come to U.S. at end of 2007", *Automotive News*, 8 May. http://www.autonews.com/apps/pbcs.dll/article?AID=/20060508/SUB/60506025

Handfield, R.B. and S.A. Melnyk (1998), "The scientific theory-building process: a primer using the case of TQM," *Journal of Operations Management*, Vol. 16 No. 4, pp. 321-339.

Harzing, A.W.K. (1999), *Managing the Multinationals: An International Study of Control Mechanisms*, Edward Elgar, Cheltenham, UK.

Hay, E.J. (1988), *The just-in-time Breakthrough: Implementing the New Manufacturing Basics*, John Wiley & Sons, New York.

Hayes, D.D. (1977), "The contingency theory of managerial accounting", *The Accounting Review*, Vol. 52 No. 1, pp. 22-39.

Heras, I., M. Casadesus and G.P.M. Dick (2002), "ISO 9000 certification and the bottom line: a comparative study of the profitability of Basque region companies", *Managerial Auditing Journal*, Vol. 17 No. 1/2, pp. 72-78.

Hodge, B.J. and W.P. Anthony (1988), *Organization Theory (Third Edition)*, Allyn and Bacon, Boston.

Hofstede, G. (1978), "The Poverty of Management Control Philosophy", *Academy of Management Review*, Vol. 3 No. 3, pp. 450-461.

Hoyle, D. (2000), *Automotive Quality Systems Handbook*, Butterworth-Heinemann, Oxford.

Huhn, W. and M. Schaper (2006), "Getting better software into manufactured products", *McKinsey on IT*, Spring, pp. 3-7.

Hunt, E.E. (1924), *Scientific Management Since Taylor: a Collection of Authoritative Papers*, McGraw-Hill, New York.

Imai, M. (1986), *Kaizen: The Key to Japan's Competitive Success*, McGraw-Hill/Irwin, New York.

Imai, M. (1997), *Gemba Kaizen: A Commonsense, Low-Cost Approach to Management*, McGraw-Hill, New York.

Ishikawa, K. (1982), *Guide to Quality Control (Second Edition)*, Asian Productivity Organization, Tokyo.

Ishikawa, K. (1985), *What is Total Quality Control? The Japanese Way*, Prentice-Hall, NJ.

Ishikawa, K. (1984), *Quality Control Circles at Work: Cases from Japan's Manufacturing and Service Sectors*, Asian Productivity Organization, Tokyo.

Ishikawa, K. (1990), *Introduction to Quality Control*, Chapman & Hall, London.

ISO (1994), “ISO 9000:1994 quality management systems – fundamentals and vocabulary”, ISO International Organisation for Standardisation, Geneva.

ISO (2000), “ISO 9001:2000 Quality management systems — requirements”, ISO International Organisation for Standardisation, Geneva.

ISO (2002), “ISO/TS 16949:2002 Quality management systems — particular requirements for the application of ISO 9001:2000 for automotive production and relevant service part organizations”, ISO International Organisation for Standardisation, Geneva.

ISO (2004), “ISO 14001:2004 Environmental management systems — requirements with guidance for use”, ISO International Organisation for Standardisation, Geneva.

ISO (2005), “ISO 9000:2005 Quality management systems — fundamentals and vocabulary”, ISO International Organisation for Standardisation, Geneva.

Jewett, D. (2005), “Nissan, Hummer rebound in J.D. Power quality study”, *Automotive News*, 23 May. http://www.autonews.com/apps/pbcs.dll/article?AID=/20050523/SUB/505230732.

Juran, J.M. (1945), *Management of inspection and quality control*, Harper & Bros, New York.

Juran, J.M. and F.M. Gryna (1988), *Juran's Quality Control Handbook (Fourth Edition)*, McGraw-Hill, New York.

Kamm, J. (1980), *The Balance of Innovative Behavior and Control in New Product Development*, DBA Dissertation, Graduate School of Business Administration, Harvard University.

Karlof, B. (1993), *Key Business Concepts, A Concise Guide*, Routledge, London

Khandwalla, P.N. (1972), “The Effect of Different Types of Competition on the Use of Management Controls”, *Journal of Accounting Research*, Vol. 10 No. 1, pp. 275-285.

Khandwalla, P.N. (1973), “Effect of Competition on the Structure of Top Management Control”, *Academy of Management Journal*, Vol. 16 No. 2, pp. 285-295.

Kisiel, R. (2003), “VW cracks down on quality problems”, *Automotive News*, 29 September. http://www.autonews.com/article.cms?articleId=45299

Kisiel, R. (2005), “Ford wants better relations with its suppliers”, *Automotive News*, 17 October. http://www.autonews.com/apps/pbcs.dll/article?AID=/20051017/SUB/510170840.

Kruger, V. (2001), “Main schools of TQM: ‘the big five’”, *The TQM Magazine*, Vol. 13 No. 3, pp. 146-155.

Krumwiede, K.R. (1998), “The Implementation Stages of Activity-Based Costing and the Impact of Contextual and Organizational Factors”, *Journal of Management Accounting Research*, No. 10, pp. 239-277.

Kurylko, D.T. (2006a), “Audi will cull product offerings”, *Automotive News*, 13 March. http://www.autonews.com/apps/pbcs.dll/article?AID=/20060313/FREE/60310038

Kurylko, D.T. (2006b), “Audi will place limits on its product options”, *Automotive News*, 8 May. http://www.autonews.com/apps/pbcs.dll/article?AID=/20060508/SUB/60505020

Kurylko, D.T. and M. Rechtin (2005), “Future products – European brands: Europeans target U.S. with new vehicles”, *Automotive News*, 29 August. http://www.autonews.com/apps/pbcs.dll/article?AID=/20050829/SUB/508290733

Lapham, E. (2005), “Going global – soccer, baguettes and Chevrolet”, *Automotive News*, 8 November. http://www.autonews.com/apps/pbcs.dll/article?AID=/20051108/SUB/51108003

Laraia, A.C., P.E. Moody and R.W. Hall (1999), *The Kaizen Blitz: Accelerating Breakthroughs in Productivity and Performance*, John Wiley & Sons, New York.

Lee, A.S. (1989), “A Scientific Methodology for MIS Case Studies”, *MIS Quarterly*, Vol. 13 No. 1, pp. 33-50.

Liker, J.K. (2004), *The Toyota Way: 14 Management Principles from the World's Greatest Manufacturer*, McGraw-Hill, New York.

Likert, R. (1932), "A Technique for the Measurement of Attitudes", *Archives of Psychology*, Vol. 140 (June).

Lowe, E.A. (1971), "On the Idea of a Management Control System: Integrating Accounting and Management Control", *Journal of Management Studies*, Vol. 8 No. 1, pp. 1-12.

Lu, D.J. (1989), *Kanban Just-In-Time at Toyota: Management Begins at the Workplace (Revised Edition)*, Edited by Japan Management Association, Productivity Press, Portland, Oregon.

Machin, J.L.J. (1983), "Management Control Systems: Whence and Whither? pp. 22-42, In: E.A. Lowe and J.L.J. Machin (eds.), *New Perspectives in Management Control*, Macmillan, London.

Mehra, S., J.M. Hoffman and D. Sirias (2001), "TQM as a management strategy for the next millennia", *International Journal of Operations & Production Management*, Vol. 21 No. 5/6, pp. 855-876.

Meiners, J. (2005), "Mercedes gets 3 SUVs from 1 platform, Unibody architecture makes it easier to build variants", *Automotive News Europe*, 19 September. http://europe.autonews.com/article.cms?articleId=56560

Meiners, J. (2006), "Zetsche will reduce options on Mercedes", *Automotive News*, 6 March.
http://www.autonews.com/apps/pbcs.dll/article?AID=/20060306/SUB/60303104

Merchant, K.A. (1982), "The control function of management", *Sloan Management Review*, Vol. 23 No. 4, pp. 43-55.

Merchant, K.A. and R. Simons (1986), "Research and Control in Complex Organizations: an Overview", *Journal of Accounting Literature*, Vol. 5, pp. 183-201.

Meredith, J. (1998), "Building operations management theory through case and field research", *Journal of Operations Management*, Vol. 16 No. 4, pp. 441-454.

Miles, R.E. and C.C. Snow (1988), *Organizational Strategy, Structure and Process*, McGraw-Hill, New York.

Miller, D. and P.H. Friesen (1982), "Innovation in Conservative and Entrepreneurial Firms", *Strategic Management Journal*, Vol. 3 No. 1, pp. 1-25.

Miltenburg, P.R. (2003), *Effects of Modular Sourcing on Manufacturing Flexibility in the Automotive Industry: A study among German OEMs*, PhD thesis, ERIM PhD Series Research in Management.

Mizuno, S. and Y. Akao (1994), *QFD: The Customer-Driven Approach to Quality Planning and Deployment*, Asian Productivity Organization, Tokyo, Japan.

Monden, Y. (1998), *Toyota Production System: An Integrated Approach to Just-In-Time (Third Edition)*, Engineering & Management Press, Norcross, Georgia.

Mukherjee, A., W. Mitchell and F.B. Talbot (2000), "The impact of new manufacturing requirements on production line productivity and quality at a focused factory", *Journal of Operations Management*, Vol. 18 No. 2, pp. 139-168.

Noori, H. (1991), "Decoupling of Product and Process Life Cycles", *International Journal of Production Research*, Vol. 29 No. 9, pp. 1853-1865.

Nunnally, J.C. (1978), *Psychometric Theory (Second Edition)*, McGraw-Hill, New York.

Nwabueze, U. (2001), "The implementation of TQM for the NHS manager", *Total Quality Management*, Vol. 12 No. 5, pp. 657-675

Ohno, T. (1988), *Toyota Production System: Beyond Large-Scale Production*, Productivity Press, Cambridge, MA.

Otley, D., J. Broadbent and A. Berry (1995), "Research in Management Control: an Overview of its Development", *British Journal of Management*, Vol. 6 No. S1, pp. S31-S44.

Oude Weernink, W. (2006a), "How technology sharing works for Ford, Concept is extended to more platforms", *Automotive News Europe*, 20 March. http://www.autonews.com/apps/pbcs.dll/article?AID=/20060320/ANE/60317078.

Oude Weernink, W. (2006b), "Ford learns a lesson from Lego", *Automotive News*, 27 March. http://www.autonews.com/apps/pbcs.dll/article?AID=/20060327/SUB/60323037.

Pagell, M., C-L. Yang, D.W. Krumwiede and C. Sheu (2004), "Does the Competitive Environment Influence the Efficacy of Investments in Environmental Management?", *Journal of Supply Chain Management*, Vol. 40 No. 3, pp. 30-39.

Pande, P.S., R.P. Neuman and R.R. Cavanagh (2000), *The Six Sigma Way: How GE, Motorola and Other Top Organizations are Honing Their Performance*, McGraw-Hill, New York.

Pande, P.S., R.P. Neuman and R.R. Cavanagh (2004), *What is Design for Six Sigma?*, McGraw-Hill, New York.

Patton, M.Q. (2001), *Qualitative Research and Evaluation Methods (Third Edition)*, Sage Publications, Thousand Oaks, California.

Phillips-Donaldson, D. (2006), "Good News – If You're Ready", *Quality Progress*, January, pp. 37-43.

Pine, B.J. II (1993), *Mass Customization - The New Frontier in Business Competition*, Harvard Business School Press, Boston, MA.

Pine, B.J. II and J.H. Gilmore (1999), *The Experience Economy: Work Is Theatre & Every Business a Stage*, Harvard Business School Press, Boston, MA.

Prater, E., M. Biehl and M.A. Smith (2001), "International supply chain agility, Tradeoffs between flexibility and uncertainty", *International Journal of Operations & Production Management*, Vol. 21 No. 5/6, pp. 823-839.

Pyzdek, T. (2003), *The Six Sigma Handbook: The Complete Guide for Greenbelts, Blackbelts, and Managers at All Levels*, McGraw-Hill, New York.

Ramos, M.M. and F.G. Hidalgo (2003), "From Diagnostic to Interactive Style of Management Control", *Management Research News*, Vol. 26 No. 5, pp. 21-31.

Rathe, A.W. (1960), "Management Controls in Business", in: D.G. Malcolm and A.J. Rowe (Eds.), *Management Control Systems*, Wiley, New York.

Rechtin, M. (2006a), "Volvo exec: Look outside for parts", *Automotive News*, 6 February.
http://www.autonews.com/apps/pbcs.dll/article?AID=/20060206/SUB/60203058.

Rechtin, M. (2006b), "Sagging Volvo sees help in '07, New vechicles, engine expected to boost sales", *Automotive News*, 27 March.
http://www.autonews.com/apps/pbcs.dll/article?AID=/20060327/SUB/60324028.

Ritchie, L. and B.G. Dale (2000), "Self-assessment Using the Business Excellence Model: a Study of Practice and Processes", *International Journal of Production Economics*, Vol. 66 No. 3, pp. 241-254.

Robson, C. (2002), *Real World Research, a Resource for Social Scientists and Practitioner-Researchers (Second Edition)*, Blackwell Publishing, Oxford.

Rogers, R.E. and R.H. McIntire (1983), *Organization and Management Theory*, John Wiley & Sons, New York.

Rust, R.T., A.J. Zahorik and T.I. Keiningham (1994), "Return on qualiy (ROQ): making service quality financially accountable", *Journal of Marketing*, Vol. 59 No. 2, pp. 58-70.

Schilling, M.A. (2000), "Toward a general modular systems theory and its application to interfirm product modularity", *Academy of Management Review*, Vol 25 No 2, pp. 312-334.

Schlie, E. and G. Yip (2000), "Regional Follows Global: Strategy Mixes in the World Automotive Industry", *European Management Journal*, Vol. 18 No. 4, pp. 343-354.

Senapati, N.R. (2004), "Six Sigma: myths and realities", *International Journal of Quality and Reliability Management*, Vol. 21 No. 6, pp. 683-690.

Shafritz, J.M. and J.S. Ott (2001), *Classics of Organization Theory (Fifth Edition)*, Wadsworth Publishing.

Sheffi, Y. and J.B. Rice Jr. (2005), "A Supply Chain View of the Resilient Enterprise", *MIT Sloan Management Review*, Vol. 47 No. 1, pp. 41-48.

Sherefkin, R. and J. LaReau (2006), “GM picks China for electronics, Purchasing unit moves from U.S. to Shanghai”, *Automotive News*, 27 February. http://www.autonews.com/apps/pbcs.dll/article?AID=/20060227/SUB/60224160

Sherefkin, R. and A. Wilson (2006), “Transmission parts idle 7 Ford plants”, Automotive News, 28 April. http://www.autonews.com/apps/pbcs.dll/article?AID=/20060428/REG/60428001

Shewhart, W.A. (1931), *Economic Control of Quality of Manufactured Product (Seventh Printing)*, D. van Nostrand Company, New York.

Shingo, S. (1986), *Zero Quality Control: Source Inspection and the Poka-Yoke System*, Productivity Press, Portland, Oregon.

Shingo, S. (1987), *The Sayings of Shigeo Shingo: Key Strategies for Plant Improvement*, Productivity Press, Portland, Oregon.

Shingo, S. (1989), *A Study of the Toyota Production System from an Industrial Engineering Viewpoint (Revised Edition)*, Productivity Press, Cambridge, MA.

Sidhu, J.S. (2004), “Business-Domain Definition and Performance: An Empirical Study”, *SAM Advanced Management Journal*, Vol. 69 No. 4, pp. 40-45.

Sim, A.B. and H.Y. Teoh (1997), “Relationship Between Business Strategy, Environment and Controls: A Three Country Study”, *Journal of Applied Business Research*, Vol. 13 No. 4, pp. 57-73.

Simon, B. (2004), “Vehicle recalls hit new high”, *The Financial Times*, 5 November.

Simons, R. (1987), “Accounting Control Systems and Business Strategy: an Empirical Analysis”, *Accounting, Organizations and Society*, Vol. 12 No. 4, pp. 357-374.

Simons, R. (1990), “The role of management control systems in creating competitive advantage: new perspectives”, *Accounting, Organizations and Society*, Vol. 15 No. 1/2, pp. 127-143.

Simons, R. (1991), “Strategic Orientation and Top Management Attention to Control Systems”, *Strategic Management Journal*, Vol. 12 No. 1, pp. 49-62.

Simons, R. (1994), "How New Top Managers Use Control Systems as Levers of Strategic Renewal", *Strategic Management Journal*, Vol. 15 No. 3, pp. 169-189.

Simons, R. (1995), *Levers of control: How managers use innovative control systems to drive strategic renewal*, Harvard Business School Press, Boston.

Simons, R. (2000), *Performance Measurement & Control Systems for Implementing Strategy, Text & Cases*, Prentice Hall, New Jersey.

Sitkin, S.B., K.M. Sutcliffe and R.G. Schroeder (1994), "Distinguishing Control From Learning in Total Quality Management: A Contingency Perspective", *The Academy of Management Review*, Vol. 19 No. 3, pp. 537-564.

Sousa, R. and C.A. Voss (2001), "Quality management: Universal or context dependent?", *Production and Operations Management*, Vol. 10 No. 4, pp. 383-404.

Sousa, R. and C.A. Voss (2002), "Quality management re-visited: a reflective review and agenda for future research", *Journal of Operations Management*, Vol. 20 No. 1, pp. 91-109.

Spear, S.J. (2004), "Learning to Lead at Toyota", *Harvard Business Review*, May, Case study, pp. 1-10.

Speklé, R.F. (2001), "Explaining management control structure variety: a transaction cost economics perspective", *Accounting, Organizations and Society*, Vol. 26 No. 4/5, pp. 419-441.

Spencer, B.A. (1994), "Models of Organization and Total Quality Management: A Comparison and Critical Evaluation", *The Academy of Management Review*, Vol. 19 No. 3, pp. 446-471.

Stacey, R.D. (1996), *Strategic Management & Organisational Dynamics (Second Edition)*, Pitman Publishing, London.

Stallkamp, T.T. (2005), *SCORE! A Better Way to Do Business: Moving from Conflict to Collaboration*, Wharton School Publishing, New Jersey.

Stamatis, D.H. (1998), *Advanced Quality Planning: A Commonsense Guide to AQP and APQP*, Productivity Press, Portland, Oregon.

Stamatis, D.H. (2003), *Failure Mode and Effect Analysis: FMEA from Theory to Execution (Second Edition)*, ASQ Quality Press, Milwaukee, Wisconsin.

Stein, J. (2005), "VW will pull niche vehicles from its 'hat', Bernhard's strategy leads to new variants", *Automotive News Europe*, 28 November. http://europe.autonews.com/article.cms?articleId=56885

Stein, J. (2006), "VW focuses on supplier quality, Carmaker wants better results in influential customer surveys", *Automotive News Europe*, 3 April. http://www.autonews.com/apps/pbcs.dll/article?AID=/20060403/ANE/60330069.

Stoffer, H. (2005), "Ford blames supplier error for 2 recalls", *Automotive News*, 12 December. http://www.autonews.com/article.cms?articleId=55636

Stoffer, H. (2006), "Fear remains a Toyota motivator, 1 caveat of growth: Quality can't slip", *Automotive News*, 20 March. http://www.autonews.com/apps/pbcs.dll/article?AID=/20060320/SUB/60316014

Tam, L.W.H. (2000), "Quality management theory and practice: some observations of practices in Australian academic libraries", *Library Management*, Vol. 21 No. 7, pp. 349-356.

Taylor, F.W. (1911), *The principles of scientific management*, Norton, New York.

Terziovski, M., D. Power and A.S. Sohal (2003), "The longitudinal effects of the ISO 9000 certification process on business performance", *European Journal of Operational Research*, Vol. 146 No. 3, pp. 580-595.

Terziovski, M., D. Samson and D. Dow (1997), "The business value of quality management systems certification: Evidence from Australia and New Zealand", *Journal of Operations Management*, Vol. 15 No. 1, pp. 1-18.

The Economist (2001), "Mass customisation, a long march", 12 July. http://www.economist.com/displaystory.cfm?story_id=691227

The Economist (2004), "Car manufacturing, ripe for revolution", 2 September, pp. 12. http://www.economist.com/displaystory.cfm?story_id=3151249

The Economist (2005), "The global car industry, extinction of the predator", 8 September. http://www.economist.com/displaystory.cfm?story_id=4369762

The Economist (2006), “British carmaking, Peugeot packs its bags”, 20 April, pp. 35-36. http://www.economist.com/displayStory.cfm?story_id=6838562

Treece, J.B. (2006a), “Toyota cost cutters use ax, not tweezers”, *Automotive News*, 20 February. http://www.autonews.com/apps/pbcs.dll/article?AID=/20060220/SUB/60216073

Treece, J.B. (2006b), “Infiniti arrives in Europe in 2008”, *Automotive News*, 25 April. http://www.autonews.com/apps/pbcs.dll/article?AID=/20060425/REG/60425008

Truss, C., L. Gratton, V. Hope-Hailey, P. McGovern and P. Stiles (1997), “Soft and hard models of human resource management: a reappraisal”, *Journal of Management Studies*, Vol. 34 No. 1, pp. 53-73.

Van der Wiele, A. (1998), *Beyond Fads: Management Fads and Organisational Change with Reference to Quality Management*, Eburon Publishers, Delft.

Van der Wiele, A., J.D. van Iwaarden, A.R.T. Williams and B.G. Dale (2005), "Perceptions about the ISO 9000 (2000) quality system standard revision and its value: The Dutch experience", *International Journal of Quality and Reliability Management*, Vol 22 No 2, pp. 101-119.

Van der Wiele, A., A.R.T. Williams, B.G. Dale, F. Kolb, D.M. Luzon, M. Wallace and A. Schmidt (1996), “Quality Management Self-assessment: an Examination in European Business”, *Journal of General Management*, Vol. 22 No. 1, pp. 48-67.

Verbeek, M. (2004), *A Guide to Modern Econometrics (Second Edition)*, John Wiley & Sons, Chichester, England.

Von Corswant, F. and P. Fredriksson (2002), “Sourcing trends in the car industry, A survey of car manufacturers’ and suppliers’ strategies and relations”, *International Journal of Operations & Production Management*, Vol. 22 No. 7, pp. 741-758.

Voss, C.A., N. Tsikriktsis and M. Frohlich (2002), "Case Research in Operations Management", *International Journal of Operations & Production Management*, Vol. 22 No. 2, pp. 195-219.

Waldman, D.A. (1994), “The Contributions of Total Quality Management to a Theory of Work Performance”, *The Academy of Management Review*, Vol. 19 No. 3, pp. 510-536.

Wernle, B. (2004), “Volvo issues its biggest recall”, *Automotive News*, 13 September. http://www.autonews.com/article.cms?articleId=49742

Wilkinson, A., T. Redman, E. Snape and M. Marchington (1998), *Managing with Total Quality Management, Theory and Practice*, Macmillan Press, London.

Womack, J.P., D.T. Jones and D. Roos (1990), *The Machine That Changed the World*, Macmillan Publishing Company, New York.

Womack, J.P and D.T. Jones (1996), *Lean Thinking: Banish Waste and Create Wealth in Your Corporation*, Simon & Schuster, New York.

Yin, R.K. (2003), *Case Study Research, Design and Methods (Third Edition)*, Sage, London.

Yong, J. and A. Wilkinson (1999), “The state of total quality management: a review”, *The International Journal of Human Resource Management*, Vol. 10 No. 1, pp. 137-161.

Appendices

Appendix 4.1: Initial Interviews with Managers

Frits Mansvelt Beck, Senior Manager e-Business, Global e-Business Centre, ING Group, 3 September 2002, 10.00 hours, ING office, Drentestraat 24, 1083 HK Amsterdam, The Netherlands

Richard Zoetemelk, Change Manager, Siemens Netherlands, 11 September 2002, 09.00 hours, Siemens office, Prinses Beatrixlaan 26, 2595 AL The Hague, The Netherlands

Martin Hogeveen, Quality Manager and Joop Addiks, Manager Quality, Safety and Environment, Getronics Installation Services, 11 September 2002, 13.00 hours, Getronics office, Einsteinbaan 2, 3430 BL Nieuwegein, The Netherlands

Ko Leenknegt, Manager Quality, Safety and Environment and Jurgen ten Siethof, Senior manager IT & GIS, Grontmij, 12 September 2002, 15.30 hours, Grontmij office, Bovendonk 29, 4700 BS Roosendaal, The Netherlands

Yno Papen, E-Business Manager, Mercedes-Benz, DaimlerChrysler Netherlands, 17 September 2002, 14.00 hours, Mercedes-Benz office, Reactorweg 25, 3542 AD Utrecht, The Netherlands

Will Daniëls, Group Manager Human Resources, Bolsius International, 18 September 2002, 13.00 hours, Bolsius office, Kerkendijk 126, 5482 KK Schijndel, The Netherlands

Andries Verschoor, Benelux Engineering and Quality Health Safety & Environment Manager, Shell Europe Oil Products – Distribution, Shell Netherlands, 23 September 2002, 10.30 hours, Shell office, Propaanweg 18, 3196 KH Vondelingenplaat Rt, The Netherlands

Appendix 4.2: Try-out Interviews with Managers

Frits van den Assem, Manager Quality and Service Department, Start Flex Company, 29 October 2003, Erasmus University Rotterdam, Burgemeester Oudlaan 50, 3062 PA Rotterdam, The Netherlands

Andries Verschoor, Benelux Engineering and Quality Health Safety & Environment Manager, Shell Europe Oil Products – Distribution, Shell Netherlands, 7 November 2003, Shell office, Propaanweg 18, 3196 KH Vondelingenplaat Rt, The Netherlands

Coen Hulleman, Head of Operations / Global Quality & Safety Manager Oils & Fats, Unilever Raw Materials BV, 23 July 2004, Unilever office, Nassaukade 3, Becelhuis 1e etage, 3071 JL Rotterdam, The Netherlands

Appendix 4.3: Interview Questions

Interview with the Quality Manager

Can you indicate what quality tools and techniques your plant has implemented over the years? Why has your plant chosen these tools and techniques?

What have been the major changes in your plant's quality approach over the years?

What have been the major triggers for your plant to change its quality management approach?

Has the importance of quality management changed over time at your plant? Why yes/no?

What developments have happened at your plant's quality department? Has the number of employees increased or decreased? Have its responsibilities been expanded or reduced?

How has the quality of the vehicles that your plant manufactures developed over time?

What changes have there been in the frequency of quality related problems with vehicles?

What changes have there been in the nature of quality related problems with vehicles? (cause, severity, impact, etc.)

What is the influence of the employee on quality related problems with vehicles?

What is the influence of outsourcing on quality related problems with vehicles?

Does your plant assemble multiple vehicles on the same platform? If yes, what is the effect of such a strategy on quality management?

What is the impact of an increasing product variety on quality management at your plant?

What is the impact of shortening product life cycles on quality management at your plant?

Interview with the Supply Chain Manager

Has your plant increased outsourcing of components to suppliers? Why yes/no?

Has your plant increased the number of supplier firms to which it outsources? Why yes/no?

Have your plant's relationships with its suppliers become more important over time? Why yes/no?

Are suppliers involved in the development of new vehicles? Has this changed over time? Why yes/no?

What types of activities are outsourced by your plant? Only manufacturing of components or also services, and research and development? How was this in the past?

What criteria are used to make the outsourcing decision? Have the criteria changed over time? Why yes/no?

How does your plant monitor its suppliers? Has this changed over time? Why yes/no?

To what extent are increasing product variety and shortening product life cycles visible in your plant's supply chain strategy?

Does outsourcing result in more or less quality problems? How does your plant cope with that? Has the occurrence of supplier quality problems increased over time? Why yes/no?

Interview with the Logistics Manager

Has your plant increased outsourcing of components to suppliers? Why yes/no?

Has your plant increased the number of supplier firms to which it outsources? Why yes/no?

Have your plant's relationships with its suppliers become more important over time? Why yes/no?

Are suppliers involved in the development of new vehicles? Has this changed over time? Why yes/no?

What types of activities are outsourced by your plant? Only manufacturing of components or also services, and research and development? How was this in the past?

What criteria are used to make the outsourcing decision? Have the criteria changed over time? Why yes/no?

How does your plant monitor its suppliers? Has this changed over time? Why yes/no?

To what extent are increasing product variety and shortening product life cycles visible in your plant's supply chain strategy?

Does outsourcing result in more or less quality problems? How does your plant cope with that? Has the occurrence of supplier quality problems increased over time? Why yes/no?

Interview with the Production Manager

How has your plant's output of vehicles developed over time?

How has the average production time of a vehicle developed over time?

How has the variety in vehicle production developed over time at your plant? How will it develop in the future? What are the effects of this development on the production processes?

To what extent have production processes changed over time at your plant? Are they likely to change in the future? Have production processes become more complex? Why?

How does your plant monitor its processes? Has this changed over time? Why yes/no?

To what extent has outsourcing influenced the production processes at your plant?

How have automation and the use of robots influenced production at your plant?

On what criteria is decided if a process should be automated?

Are your satisfied with the way robots perform in your plant's production processes?

Is there a need to make production more flexible than in the past? If yes, when did that need emerge and how has your plant coped with it?

Can automation and robots help to make production more flexible or do they make production less flexible?

What changes have happened within your plant with respect to production planning?

Has there been a change in the frequency and severity of production errors in your plant's processes?

Has process control become easier over time, or more difficult? Why?

Is there enough time to learn from production errors and to implement them in the processes? Has this become easier over time, or harder? Why?

Is information about one vehicle's production errors useful for the next vehicle, if the next vehicle is completely different?

Has the quality of your plant's vehicles improved over time? Will it improve in the future?

What environmental factors make it hard to improve the quality of the vehicles? Why?

To what extent does your plant make use of self-steering teams? How has this developed over time?

How has the variety of jobs (fields of expertise) within your plant changed over time?

Does your plant employ many flex workers? What developments have been going on in respect to flex work? What is expected for the future?

To what extent does your plant empower its employees? How has this changed from the past? Will it change in the future?

To what extent does your plant discuss problems with its employees? Has this changed over time? Why yes/no?

Does your plant encourage its employees to make suggestions for improvements of processes and products? Has this changed over time? Why yes/no?

Are there clear boundaries within which the employees have to operate? Have there always been clear boundaries? If the importance of setting boundaries has changed over time, why was that necessary?

What are the major changes in your plant's production management that are expected for the future? What will cause these changes?

Interview with the Human Resources Manager

How has the total number of employees at your plant developed over time?

How has the number of employees developed compared to the production of vehicles? (e.g. number of employees per vehicle)

How has the productivity of your plant's employees developed?

What developments have there been in the job requirements (knowledge, experience)? Did the criteria for the selection of new employees change over time? Why yes/no?

How have your plant's budgets for training and development changed over time?

In what kind of training does your plant put most of its effort/budget?

Has the importance of training increased over time? Why yes/no?

To what extent does your plant make use of self-steering teams? How has this developed over time?

How has the variety of jobs (fields of expertise) within your plant changed over time?

Does your plant employ many flex workers? What developments have been going on in respect to flex work? What is expected for the future?

How have your plant's HR practices developed over time? Where is the current focus?

To what extent does your plant empower its employees? How has this changed from the past? Will it change in the future?

To what extent does your plant discuss problems with its employees? Has this changed over time? Why yes/no?

Does your plant encourage its employees to make suggestions for improvements of processes and products? Has this changed over time? Why yes/no?

Have there been changes in the hierarchical structure within your plant? Has it become flatter or taller? Why?

Does your plant use performance related pay? Did your plant use it in the past? Is your plant planning to use it in the future? Which performance criteria are used for performance related pay?

Are there clear boundaries within which the employees have to operate? Have there always been clear boundaries? If the importance of setting boundaries has changed over time, why was that necessary?

Nearly every vehicle is unique in its specifications because it is made to the wishes of the consumer. How does this variety of products affect the HR function at your plant?

What are the major changes in your plant's HR management that are expected for the future? What will cause these changes?

Interview with the Quality Manager at a First Tier Supplier

Can you indicate what quality tools and techniques your plant has implemented over the years? Why has your plant chosen these tools and techniques?

What have been the major changes in your plant's quality approach over the years?

What have been the major triggers for your plant to change its quality management approach?

Has the importance of quality management changed over time at your plant? Why yes/no?

What changes have there been in the frequency and nature of quality related problems with products? (cause, severity, impact, etc.)

What is the impact of an increasing product variety and shortening product life cycles on quality management at your plant?

What types of activities are outsourced to your plant by your customer? Only manufacturing of components or also services, and research and development? How was this in the past?

How has your customer's approach towards your plant changed over the years (e.g. changing emphasis, more responsibilities)?

Does your customer involve your plant in the development of new vehicles? Has this changed over time? Why yes/no?

How does your customer monitor your plant? Has this changed over time? Why yes/no?

Are the demands of your customer tough? (e.g. yearly cost reduction)

Does your customer help your plant to improve its processes? If yes, how?

To what extent have production processes changed over time at your plant as a result of demands from your customer? Are they likely to change in the future? Have production processes become more complex? Why?

Is there a need to make production more flexible than in the past to comply with the demands of your customer? If yes, when did that need emerge and how has your plant coped with it?

Has process control become easier over time, or more difficult? Why?

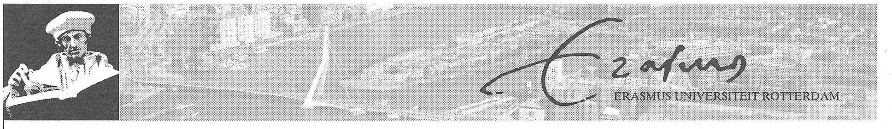
Is there enough time to learn from production errors and to implement them in the processes? Has this become easier over time, or harder? Why?

What developments have there been in the job requirements (knowledge, experience)? Did the criteria for the selection of new employees change over time? Why yes/no? Did your customer's demands influence these changes?

Has the importance of training increased over time? Why yes/no?

What are the major changes in your plant's relation with your customer that are expected for the future? What will cause these changes?

Appendix 9.1:
Cover Letter and Survey Questionnaire in English



Erasmus Universiteit Rotterdam

To the quality manager

Business & Management
Address Burg Oudlaan 50, Rotterdam
Postal address Room H9-01, PO Box 1738
NL-3000 DR Rotterdam
The Netherlands
Phone +31 6 108 193 90
Fax +31 10 408 9169
E-mail vaniwaarden@few.eur.nl
Internet www.few.eur.nl/few/people/vaniwaarden

Date
October 2005

Subject
Questionnaire survey automotive industry

Dear quality manager,

Would you please fill out the attached questionnaire? The questionnaire is part of a four-year study on quality management in the automotive industry, by:

- Erasmus University Rotterdam, The Netherlands (Prof. Dr. A.R.T. Williams)
- The University of Manchester, United Kingdom (Prof. Dr. B.G. Dale)
- The Technische Universität Kaiserslautern, Germany (Prof. Dr. K.J. Zink)

The questionnaire deals with changes in quality management and control as a result of the current trends towards more diverse product offerings and shortening product life cycles.

The questionnaire is sent to quality managers at supplier plants in the automotive industry. If you are one of them, you would help our research a lot if you would take the time to fill out the questionnaire. If your plant does not employ a quality manager, the questionnaire would best be filled out by the most senior person who is responsible for quality management.

The questionnaire is anonymous, but if you wish to be kept informed about the results of this study, you can fill out your e-mail address at the end of the questionnaire.

Thank you very much in advance for your willingness to support our research!

Kind regards,

Jos van Iwaarden

Attachments:

- Questionnaire
- Pre-printed FREEPOST return envelope

Changing Quality Controls – Questionnaire

Plant characteristics

1. **Please indicate approximately what proportion/percentage of your plant is engaged in manufacturing and what proportion in service**

   Manufacturing: ☐ 0-20% ☐ 21-40% ☐ 41-60% ☐ 61-80% ☐ 81-100%
   Service: ☐ 0-20% ☐ 21-40% ☐ 41-60% ☐ 61-80% ☐ 81-100%

2. **Please indicate the size of your plant by number of employees**

   ☐ Less than 10 employees
   ☐ 10 – 50 employees
   ☐ 51 – 100 employees
   ☐ 101 – 500 employees
   ☐ 501 – 1000 employees
   ☐ More than 1000 employees

3. **Please indicate the ownership of your company**

   ☐ Privately owned company
   ☐ Listed on the stock market
   ☐ Part of a large group that has its headquarters in the following country (please specify)

4. **Please indicate how long your plant has been active in the automotive industry**

   ☐ less than 2 years ☐ 2 – 5 years ☐ 6 – 10 years ☐ 11 – 15 years ☐ more than 15 years

5. **Please indicate how long you have been working at your plant**

   ☐ less than 2 years ☐ 2 – 5 years ☐ 6 – 10 years ☐ 11 – 15 years ☐ more than 15 years

6. **Please indicate your job title**

7. **Please indicate all automotive groups to which your plant supplies**

   CAR OEMS

   ☐ BMW *BMW, Mini, Rolls-Royce*
   ☐ DaimlerChrysler *Mercedes-Benz, Chrysler, Jeep, Dodge, Smart, Maybach*
   ☐ Fiat *Fiat, Alfa-Romeo, Lancia, Ferrari, Maserati*
   ☐ Ford *Ford, Volvo, Jaguar, Land Rover, Aston Martin*
   ☐ General Motors *General Motors, Opel, Vauxhall, Saab, Chevrolet, Cadillac, Hummer, Holden*
   ☐ Honda
   ☐ Hyundai *Hyundai, Kia*
   ☐ Mazda
   ☐ Mitsubishi
   ☐ Porsche
   ☐ PSA *Peugeot, Citroen*
   ☐ Renault/Nissan *Renault, Nissan, Infiniti, Dacia*
   ☐ Subaru
   ☐ Suzuki
   ☐ Toyota *Toyota, Lexus, Daihatsu*
   ☐ Volkswagen *Volkswagen, Audi, Seat, Skoda, Bentley, Bugatti, Lamborghini*
   ☐ Other car OEM (please specify)

TRUCK OEMS

- ☐ DaimlerChrysler Trucks *Mercedes-Benz, Freightliner, Mitsubishi Fuso*
- ☐ Hino
- ☐ Isuzu
- ☐ Iveco
- ☐ MAN
- ☐ Nissan Diesel
- ☐ Paccar *DAF, Leyland, Peterbilt, Kenworth, Foden*
- ☐ Renault Trucks
- ☐ Scania
- ☐ Volvo Trucks *Volvo, RVI, Mack*
- ☐ Other truck OEM (please specify)

OTHER AUTOMOTIVE SUPPLIERS AND ORGANISATIONS (PLEASE SPECIFY)

8. Please indicate which product groups your plant supplies

- ☐ Chassis *e.g. Suspension, axles, wheels, brakes, steering system*
- ☐ Power train *e.g. Engine, transmission, fuel system, exhaust*
- ☐ Exterior trim + body *e.g. Body assemblies, bumpers, lights, mirrors*
- ☐ Interior trim *e.g. Instrument panel, seats, airbags, carpets, headliner*
- ☐ Electrical/Electronics *e.g. Wiring, circuitry, safety systems, navigation, entertainment*
- ☐ Other (please specify)

Product variety and product life cycle length

The next set of questions deals with your individual perceptions about changes which have taken place at your plant. Would you please fill out these questions, regardless of how long you have been working at your plant?

9. Please indicate to what extent you agree with the following statements about your plant, both today and ten years ago

Each statement has two scales: the **left scale** is for your perceptions about the **current situation in your plant** and the **right scale** is for your perceptions about the **situation that existed in your plant ten years ago**.

1 = completely disagree	completely disagree = 1
2 = somewhat disagree	somewhat disagree = 2
3 = undecided	undecided = 3
4 = somewhat agree	somewhat agree = 4
5 = completely agree	completely agree = 5

TODAY		10 YEARS AGO
1 2 3 4 5	Customer demand is predictable	1 2 3 4 5
1 2 3 4 5	Customer demand is changing rapidly	1 2 3 4 5
1 2 3 4 5	My plant offers products in a wide range of configurations	1 2 3 4 5
1 2 3 4 5	Customers are willing to pay extra for additional product variety	1 2 3 4 5
1 2 3 4 5	My plant offers more product variety than our competitors	1 2 3 4 5
1 2 3 4 5	Customers are actively assisting my plant in delivering product variety	1 2 3 4 5
1 2 3 4 5	Fashion trends and style have an influence on customer demand	1 2 3 4 5
1 2 3 4 5	It is important to respond quickly to changing customer demands with new or modified products	1 2 3 4 5

1	2	3	4	5	Our products have short life cycles	1	2	3	4	5
1	2	3	4	5	Product innovations are important to the success of my plant	1	2	3	4	5
1	2	3	4	5	Production technologies are changing rapidly	1	2	3	4	5
1	2	3	4	5	My plant is dependent on investments in technology	1	2	3	4	5
1	2	3	4	5	Customers dictate prices, conditions, and product features	1	2	3	4	5
1	2	3	4	5	Customers could not easily switch to an alternative supplier	1	2	3	4	5
1	2	3	4	5	Competition is strong	1	2	3	4	5
1	2	3	4	5	Demands of customers on quality are tough	1	2	3	4	5
1	2	3	4	5	Demands of customers on delivery performance are tough	1	2	3	4	5
1	2	3	4	5	Demands of customers on costs are tough	1	2	3	4	5
1	2	3	4	5	Our products meet our customers' needs and wants	1	2	3	4	5
1	2	3	4	5	Customers are willing to share sensitive information with my plant	1	2	3	4	5
1	2	3	4	5	Production processes in my plant are characterised by large batch sizes	1	2	3	4	5
1	2	3	4	5	My plant has flexible production processes	1	2	3	4	5
1	2	3	4	5	To cope with demand fluctuations my plant uses labour rather than automation	1	2	3	4	5
1	2	3	4	5	Stock levels of finished goods are large in my plant	1	2	3	4	5
1	2	3	4	5	Stock levels of supplies are large in my plant	1	2	3	4	5

10. To what extent does your plant provide less or more product variety today than ten years ago?

- ☐ Much less product variety today
- ☐ Somewhat less
- ☐ The same amount
- ☐ Somewhat more
- ☐ Much more product variety today

11. To what extent does your plant expect to provide less or more product variety in the future?

- ☐ Much less product variety in the future
- ☐ Somewhat less
- ☐ The same amount
- ☐ Somewhat more
- ☐ Much more product variety in the future

12. Please indicate the approximate average life cycle length of your plant's products, both today and ten years ago

Today: ☐ years Ten years ago: ☐ years

13. To what extent does your plant expect the average life cycle length of its products to increase or decrease in the future?

- ☐ Much longer product life cycles in the future
- ☐ Somewhat longer
- ☐ Equally long
- ☐ Somewhat shorter
- ☐ Much shorter product life cycles in the future

14. Please indicate how product variety influences the management of the following aspects, both today and ten years ago

Each statement has two scales: the **left scale** is for your perceptions about the **current extent of product variety offered by your plant** and the **right scale** is for your perceptions about the **product variety that your plant offered ten years ago**.

1 = Very easy to manage	Very easy to manage = 1
2 = Somewhat easy to manage	Somewhat easy to manage = 2
3 = Neutral	Neutral = 3
4 = Somewhat difficult to manage	Somewhat difficult to manage = 4
5 = Very difficult to manage	Very difficult to manage = 5

TODAY						10 YEARS AGO				
1	2	3	4	5	Quality of our products	1	2	3	4	5
1	2	3	4	5	Quality of our processes	1	2	3	4	5
1	2	3	4	5	Delivery performance of my plant	1	2	3	4	5
1	2	3	4	5	Costs of my plant	1	2	3	4	5
1	2	3	4	5	Costs of our final products	1	2	3	4	5
1	2	3	4	5	Length of our product development processes	1	2	3	4	5
1	2	3	4	5	Employee performance of my plant	1	2	3	4	5
1	2	3	4	5	The performance of our suppliers	1	2	3	4	5
1	2	3	4	5	Number of product recalls by my plant	1	2	3	4	5
1	2	3	4	5	Product demand fluctuations	1	2	3	4	5
1	2	3	4	5	Satisfaction of our customers	1	2	3	4	5
1	2	3	4	5	Satisfaction of our employees	1	2	3	4	5
1	2	3	4	5	Employee knowledge level	1	2	3	4	5
1	2	3	4	5	Time needed for interaction with our customers	1	2	3	4	5
1	2	3	4	5	Time needed for interaction with our suppliers	1	2	3	4	5

15. Please indicate how the length of your products' life cycles influences the management of the following aspects, both today and ten years ago

Each statement has two scales: the **left scale** is for your perceptions about the **current life cycle length in your plant** and the **right scale** is for your perceptions about the **life cycle length that existed in your plant ten years ago**.

1 = Very easy to manage	Very easy to manage = 1
2 = Somewhat easy to manage	Somewhat easy to manage = 2
3 = Neutral	Neutral = 3
4 = Somewhat difficult to manage	Somewhat difficult to manage = 4
5 = Very difficult to manage	Very difficult to manage = 5

TODAY						10 YEARS AGO				
1	2	3	4	5	Quality of our products	1	2	3	4	5
1	2	3	4	5	Quality of our processes	1	2	3	4	5
1	2	3	4	5	Delivery performance of my plant	1	2	3	4	5
1	2	3	4	5	Costs of my plant	1	2	3	4	5
1	2	3	4	5	Costs of our final products	1	2	3	4	5
1	2	3	4	5	Length of our product development processes	1	2	3	4	5
1	2	3	4	5	Employee performance of my plant	1	2	3	4	5
1	2	3	4	5	The performance of our suppliers	1	2	3	4	5
1	2	3	4	5	Number of product recalls by my plant	1	2	3	4	5
1	2	3	4	5	Product demand fluctuations	1	2	3	4	5
1	2	3	4	5	Satisfaction of our customers	1	2	3	4	5
1	2	3	4	5	Satisfaction of our employees	1	2	3	4	5
1	2	3	4	5	Employee knowledge level	1	2	3	4	5
1	2	3	4	5	Time needed for interaction with our customers	1	2	3	4	5
1	2	3	4	5	Time needed for interaction with our suppliers	1	2	3	4	5

Quality management

16. Please indicate to what extent you agree with the following statements about quality management in your plant, both today and ten years ago

Each statement has two scales: the **left scale** is for your perceptions about the **current situation in your plant** and the **right scale** is for your perceptions about the **situation that existed in your plant ten years ago**.

1 = completely disagree	completely disagree = 1
2 = somewhat disagree	somewhat disagree = 2
3 = undecided	undecided = 3
4 = somewhat agree	somewhat agree = 4
5 = completely agree	completely agree = 5

TODAY						10 YEARS AGO				
1	2	3	4	5	The quality of our products is excellent	1	2	3	4	5
1	2	3	4	5	Quality problems are predictable	1	2	3	4	5
1	2	3	4	5	Our suppliers determine the quality of our final products	1	2	3	4	5
1	2	3	4	5	A defect free performance is essential for my plant to survive	1	2	3	4	5
1	2	3	4	5	It is a problem for my plant to keep the number of defects low	1	2	3	4	5
1	2	3	4	5	Customers are more focused on costs than on quality	1	2	3	4	5
1	2	3	4	5	Customers are more focused on delivery performance than on quality	1	2	3	4	5
1	2	3	4	5	After delivery of our products to our customers, my plant is not responsible for defects that occur	1	2	3	4	5
1	2	3	4	5	Quality management is important for my plant	1	2	3	4	5
1	2	3	4	5	The expertise of our quality department is sufficient	1	2	3	4	5
1	2	3	4	5	Our customers' accountants have a strong influence on the specifications of the products that my plant offers	1	2	3	4	5
1	2	3	4	5	My plant promotes teamwork	1	2	3	4	5
1	2	3	4	5	All our employees have clear improvement objectives	1	2	3	4	5
1	2	3	4	5	Training of our employees is necessary to keep up with developments	1	2	3	4	5
1	2	3	4	5	Training of our suppliers is seen as our responsibility	1	2	3	4	5
1	2	3	4	5	Fluctuations in customer demand have a negative influence on the quality of our products	1	2	3	4	5
1	2	3	4	5	Customers outsource products/processes that are not critical to them	1	2	3	4	5
1	2	3	4	5	Outsourcing of parts of the production process to specialists is essential to cope with manufacturing complexity	1	2	3	4	5
1	2	3	4	5	It is difficult to trace back the cause of a defect product to its origin	1	2	3	4	5
1	2	3	4	5	My plant measures quality during the production process	1	2	3	4	5
1	2	3	4	5	My plant measures quality at the end of the production process	1	2	3	4	5
1	2	3	4	5	Quality problems are often related to non-technical/emotional issues	1	2	3	4	5

17. Please indicate to what extent you agree with the following statements about the quality maturity of your plant, both today and ten years ago

Each statement has two scales: the **left scale** is for your perceptions about the **current situation in your plant** and the **right scale** is for your perceptions about the **situation that existed in your plant ten years ago**.

1 = completely disagree	completely disagree = 1
2 = somewhat disagree	somewhat disagree = 2
3 = undecided	undecided = 3
4 = somewhat agree	somewhat agree = 4
5 = completely agree	completely agree = 5

TODAY						10 YEARS AGO				
1	2	3	4	5	We do not know why we have problems with quality	1	2	3	4	5
1	2	3	4	5	We are asking ourselves if it is absolutely necessary to always have problems with quality	1	2	3	4	5
1	2	3	4	5	Through management commitment and quality improvement we are identifying and solving problems	1	2	3	4	5
1	2	3	4	5	Defect prevention is a routine part of our operations	1	2	3	4	5
1	2	3	4	5	We know why we do not have problems with quality	1	2	3	4	5

Management control

18. Please indicate to what extent you agree with the following statements about management control in your plant, both today and ten years ago

Each statement has two scales: the **left scale** is for your perceptions about the **current situation in your plant** and the **right scale** is for your perceptions about the **situation that existed in your plant ten years ago**.

1 = completely disagree	completely disagree = 1
2 = somewhat disagree	somewhat disagree = 2
3 = undecided	undecided = 3
4 = somewhat agree	somewhat agree = 4
5 = completely agree	completely agree = 5

TODAY						10 YEARS AGO				
1	2	3	4	5	My plant clearly communicates its mission and vision to employees	1	2	3	4	5
1	2	3	4	5	My plant has clear codes of conduct for employees	1	2	3	4	5
1	2	3	4	5	My plant uses plans and budgets that are monitored for deviations	1	2	3	4	5
1	2	3	4	5	Managers of my plant personally involve themselves in decision activities of subordinates	1	2	3	4	5
1	2	3	4	5	Our customers help my plant in case of quality problems	1	2	3	4	5
1	2	3	4	5	Our customers enforce strict quality targets on my plant	1	2	3	4	5
1	2	3	4	5	Failing to meet customer's quality targets has severe consequences for my plant	1	2	3	4	5
1	2	3	4	5	Our customers are clear about the quality they expect now and in the future	1	2	3	4	5
1	2	3	4	5	Our customers involve my plant at an early stage in the development of new products	1	2	3	4	5
1	2	3	4	5	My plant has clear rules about sharing company information with suppliers	1	2	3	4	5
1	2	3	4	5	Contracts between my plant and its customers are very detailed	1	2	3	4	5
1	2	3	4	5	Advanced computer systems are essential to monitor the production processes in my plant	1	2	3	4	5
1	2	3	4	5	Our customers define precisely which aspects of the products my plant is allowed to change and which not	1	2	3	4	5
1	2	3	4	5	Enforcing strict working procedures upon employees helps to improve quality in my plant	1	2	3	4	5

1	2	3	4	5	Empowerment of our employees is essential to produce the variety of products that our customers require	1	2	3	4	5
1	2	3	4	5	Our employees are stimulated to take part in training courses	1	2	3	4	5
1	2	3	4	5	Joint training courses between my plant and our customers are used to exchange ideas	1	2	3	4	5
1	2	3	4	5	Frequent meetings between different specialist in my plant are necessary to solve quality problems	1	2	3	4	5
1	2	3	4	5	Collecting data and comparing it to specifications is essential for my plant to solve problems	1	2	3	4	5
1	2	3	4	5	Computer systems are necessary to store knowledge from previous products and reuse that knowledge for new products	1	2	3	4	5
1	2	3	4	5	To improve the quality of our products it is essential that we have a long-term improvement strategy	1	2	3	4	5
1	2	3	4	5	My plant regularly communicates its quality strategy to the employees	1	2	3	4	5
1	2	3	4	5	My plant sticks to a number of quality principles which are not negotiable with customers	1	2	3	4	5
1	2	3	4	5	In my plant quality improvement tools are always linked to tangible results	1	2	3	4	5
1	2	3	4	5	Quality control systems in my plant are flexible enough to cope with sudden changes in customer requirements	1	2	3	4	5
1	2	3	4	5	Poka yoke (mistake proofing) systems are necessary to prevent employees from making mistakes	1	2	3	4	5
1	2	3	4	5	The acceptable levels of product and service quality are clearly laid down in my plant's strategy	1	2	3	4	5
1	2	3	4	5	My plant makes use of cross functional teams	1	2	3	4	5
1	2	3	4	5	Despite the pressure to deliver on time, my plant always performs stringent product quality checks	1	2	3	4	5
1	2	3	4	5	Even in an emergency agreed quality levels cannot be sacrificed	1	2	3	4	5
1	2	3	4	5	My plant explains to employees clearly and regularly that all defects are unacceptable	1	2	3	4	5

19. Please indicate how the following performance indicators have developed for your plant over the last ten years

1 = Declined very much
2 = Declined somewhat
3 = Stayed the same
4 = Increased somewhat
5 = Increased very much

1	2	3	4	5	Operating profit
1	2	3	4	5	Customer satisfaction
1	2	3	4	5	Production volumes
1	2	3	4	5	Efficiency
1	2	3	4	5	Manufacturing flexibility
1	2	3	4	5	Plant utilisation
1	2	3	4	5	Manufacturing costs
1	2	3	4	5	Defect rate (Parts Per Million)
1	2	3	4	5	Delivery performance
1	2	3	4	5	Raw material stocks
1	2	3	4	5	Work in progress
1	2	3	4	5	Finished goods inventory
1	2	3	4	5	Amount of floor space needed

Thank you very much for your valuable time!

If you want to be kept informed about the results of this research project, please provide your e-mail address (or enclose your business card)

Please return the questionnaire in the enclosed envelope, to the following FREEPOST address:
Erasmus University Rotterdam,
Tulay Varisli, Room H15-01
Antwoordnummer 5187
3000 VB Rotterdam
The Netherlands

Appendix 9.2:
Cover Letter and Survey Questionnaire in German

TECHNISCHE UNIVERSITÄT
KAISERSLAUTERN

TU Kaiserslautern, Postfach 3049, D-67653 Kaiserslautern

Lehrstuhl für
Industriebetriebslehre und Arbeitswissenschaft

Prof. Dr. Klaus J. Zink

Gottlieb-Daimler-Straße
D-67663 Kaiserslautern

Gebäude 42, Zimmer 316

Telefon (0631) 205 - 2027
Telefax (0631) 205 - 3397

e-mail: kjzink@wiwi.uni-kl.de
http://www.lia-kl.de

An den Leiter / die Leiterin
Qualitätsmanagement

Datum
November 2005

Sehr geehrte Damen und Herren,

heute wende ich mich mit einer besonderen Bitte an Sie: Der Fragebogen im Anhang ist Teil einer internationalen Studie zum Qualitätsmanagement in der Automotive Industrie, die gemeinsam von der Technischen Universität Kaiserslautern (Prof. Dr. K.J. Zink), der Erasmus University Rotterdam (Prof. Dr. A.R.T. Williams) und der University of Manchester (Prof. Dr. B.G. Dale) durchgeführt wird.

Der Fragebogen befasst sich mit den Veränderungen im Qualitätsmanagement und in der Qualitätskontrolle, die aus den aktuellen Entwicklungen in Richtung einer größeren Produktvielfalt und der Verkürzung der Produktlebenszyklen resultieren.

Die Befragung richtet sich an Qualitätsmanager von Zulieferunternehmen aus der Automotive Industrie. Als solcher würden Sie unser Forschungsprojekt sehr unterstützen, wenn Sie sich die Zeit nähmen, den Fragebogen auszufüllen.

Die Befragung ist anonym. Wenn Sie über die Ergebnisse der Studie informiert werden möchten, können Sie Ihre eMail-Adresse per Fax (+31 10 408 9169) oder per eMail (vaniwaarden@few.eur.nl) an uns senden. Die Anonymität Ihrer Antworten ist damit sichergestellt.

Vielen Dank für Ihre Unterstützung!

Mit freundlichen Grüßen

Prof. Dr. Klaus J. Zink

Anhang:

- Fragebogen
- Adressierter und frankierter Rückumschlag

TECHNISCHE UNIVERSITÄT KAISERSLAUTERN

ERASMUS UNIVERSITEIT ROTTERDAM

MANCHESTER 1824

Fragebogen zu Veränderungen im Qualitätswesen

Betriebsmerkmale

1. Bitte geben Sie ungefähr an, zu welchem Anteil/Prozentsatz Ihr Werk sich mit Fertigung beschäftigt und wie hoch der Serviceanteil ist

Fertigung:	□ 0-20%	□ 21-40%	□ 41-60%	□ 61-80%	□ 81-100%
Service:	□ 0-20%	□ 21-40%	□ 41-60%	□ 61-80%	□ 81-100%

2. Bitte geben Sie an, wie viele Mitarbeiter in Ihrem Werk beschäftigt sind

□ Weniger als 10 Mitarbeiter
□ 10 – 50 Mitarbeiter
□ 51 – 100 Mitarbeiter
□ 101 – 500 Mitarbeiter
□ 501 – 1000 Mitarbeiter
□ Mehr als 1000 Mitarbeiter

3. Bitte charakterisieren Sie die Eigentumsverhältnisse an Ihrem Unternehmen

□ Nicht-börsennotiertes Unternehmen
□ Börsennotiertes Unternehmen
□ Teil einer großen Gruppe mit Zentrale in folgendem Land (bitte angeben)

4. Bitte geben Sie an, wie lange Ihr Werk schon in der Automobilindustrie aktiv ist

□ weniger als 2 Jahre □ 2 – 5 Jahre □ 6 – 10 Jahre □ 11 – 15 Jahre □ mehr als 15 Jahre

5. Bitte geben Sie an, wie lange Sie schon in Ihrem Werk arbeiten

□ weniger als 2 Jahre □ 2 – 5 Jahre □ 6 – 10 Jahre □ 11 – 15 Jahre □ mehr als 15 Jahre

6. Wie lautet Ihre Stellenbezeichnung?

7. Bitte nennen Sie alle von Ihrem Werk belieferten Automobilkonzerne

<u>PKW-OEMs</u>

□ BMW	*BMW, Mini, Rolls-Royce*
□ DaimlerChrysler	*Mercedes-Benz, Chrysler, Jeep, Dodge, Smart, Maybach*
□ Fiat	*Fiat, Alfa-Romeo, Lancia, Ferrari, Maserati*
□ Ford	*Ford, Volvo, Jaguar, Land Rover, Aston Martin*
□ General Motors	*General Motors, Opel, Vauxhall, Saab, Chevrolet, Cadillac, Hummer, Holden*
□ Honda	
□ Hyundai	*Hyundai, Kia*
□ Mazda	
□ Mitsubishi	
□ Porsche	
□ PSA	*Peugeot, Citroën*
□ Renault/Nissan	*Renault, Nissan, Infiniti, Dacia*
□ Subaru	
□ Suzuki	
□ Toyota	*Toyota, Lexus, Daihatsu*
□ Volkswagen	*Volkswagen, Audi, Seat, Skoda, Bentley, Bugatti, Lamborghini*
□ Sonstige Automobil-OEMs (bitte angeben)	

NUTZFAHRZEUG-OEMS

- ☐ DaimlerChrysler Trucks *Mercedes-Benz, Freightliner, Mitsubishi Fuso*
- ☐ Hino
- ☐ Isuzu
- ☐ Iveco
- ☐ MAN
- ☐ Nissan Diesel
- ☐ Paccar *DAF, Leyland, Peterbilt, Kenworth, Foden*
- ☐ Renault Trucks
- ☐ Scania
- ☐ Volvo Trucks *Volvo, RVI, Mack*
- ☐ Sonstige Nutzfahrzeug-OEMs (bitte angeben)

SONSTIGE AUTOMOBILZULIEFERER UND ANDERE UNTERNEHMEN (BITTE ANGEBEN)

8. Bitte nennen Sie die von Ihrem Werk gelieferten Produktgruppen

- ☐ Fahrwerk *z.B. Aufhängung, Achsen, Räder, Bremsen, Lenksystem*
- ☐ Antrieb *z.B. Motor, Getriebe, Kraftstoffsystem, Abgasanlage*
- ☐ Außenausstattung + Karosserie *z.B. Karosseriebau, Stoßstangen, Beleuchtung, Spiegel*
- ☐ Innenausstattung *z.B. Armaturen, Sitze, Airbags, Teppiche, Dachhimmel*
- ☐ Elektrik/Elektronik *z.B. Verkabelung, Schaltungen, Sicherheitssysteme, Navigation*
- ☐ Sonstiges (bitte angeben)

Produktvielfalt und Produktlebenszyklus

Die nächste Fragenreihe betrifft Ihre individuelle Wahrnehmung von Veränderungen, die in Ihrem Werk stattgefunden haben. Bitte beantworten Sie die Fragen, ganz gleich, wie lange Sie in Ihrem Werk arbeiten.

9. Bitte geben Sie an, inwieweit Sie folgenden Aussagen über Ihr Werk zustimmen – bezogen auf heute und bezogen auf die Zeit vor zehn Jahren.

Zu jeder Aussage gibt es zwei Bewertungsskalen: die **linke Skala** bezieht sich auf Ihre Wahrnehmung der **aktuellen Situation in Ihrem Werk** und die **rechte Skala** bezieht sich auf Ihre Wahrnehmung der **Situation, die in Ihrem Werk vor zehn Jahren herrschte**.

1 = überhaupt nicht einverstanden	überhaupt nicht einverstanden = 1
2 = teilweise nicht einverstanden	teilweise nicht einverstanden = 2
3 = unentschieden	unentschieden = 3
4 = teilweise einverstanden	teilweise einverstanden = 4
5 = vollständig einverstanden	vollständig einverstanden = 5

HEUTE						VOR 10 JAHREN				
1	2	3	4	5	Die Kundennachfrage ist prognostizierbar	1	2	3	4	5
1	2	3	4	5	Die Kundennachfrage ändert sich schnell	1	2	3	4	5
1	2	3	4	5	Mein Werk bietet Produkte in zahlreichen Konfigurationen an	1	2	3	4	5
1	2	3	4	5	Kunden sind bereit, für zusätzliche Produktvielfalt mehr zu zahlen	1	2	3	4	5
1	2	3	4	5	Mein Werk bietet mehr Produktvielfalt als unsere Konkurrenten	1	2	3	4	5
1	2	3	4	5	Kunden unterstützen mein Werk aktiv, die geforderte Produktvielfalt anbieten zu können	1	2	3	4	5
1	2	3	4	5	Modetrends und -stile haben Einfluss auf die Kundennachfrage	1	2	3	4	5

1	2	3	4	5	Es ist wichtig, auf sich ändernde Kundennachfrage schnell mit neuen oder modifizierten Produkten zu reagieren	1	2	3	4	5
1	2	3	4	5	Unsere Produkte haben kurze Lebenszyklen	1	2	3	4	5
1	2	3	4	5	Produktinnovationen sind für den Erfolg meines Werks wichtig	1	2	3	4	5
1	2	3	4	5	Die Produktionstechnologien ändern sich schnell	1	2	3	4	5
1	2	3	4	5	Mein Werk hängt von Investitionen in Technologie ab	1	2	3	4	5
1	2	3	4	5	Kunden diktieren Preise, Bedingungen und Produktmerkmale	1	2	3	4	5
1	2	3	4	5	Kunden könnten nicht ohne weiteres zu einem anderen Lieferanten wechseln	1	2	3	4	5
1	2	3	4	5	Der Wettbewerb ist hart	1	2	3	4	5
1	2	3	4	5	Die Qualitätsanforderungen der Kunden sind hoch	1	2	3	4	5
1	2	3	4	5	Die Kundenanforderungen bezüglich der Liefertreue sind hoch	1	2	3	4	5
1	2	3	4	5	Die Kostenanforderungen der Kunden sind hoch	1	2	3	4	5
1	2	3	4	5	Unsere Produkte erfüllen die Bedürfnisse und Wünsche unserer Kunden	1	2	3	4	5
1	2	3	4	5	Unsere Kunden sind bereit, mit meinem Werk sensible Informationen zu teilen	1	2	3	4	5
1	2	3	4	5	Die Produktionsprozesse in meinem Werk sind durch große Losgrößen gekennzeichnet	1	2	3	4	5
1	2	3	4	5	Mein Werk hat flexible Produktionsprozesse	1	2	3	4	5
1	2	3	4	5	Um Nachfrageschwankungen zu bewältigen, setzt mein Werk eher auf Arbeitskraft als auf Automation	1	2	3	4	5
1	2	3	4	5	Die Lagerbestände an Fertigprodukten sind in meinem Werk groß	1	2	3	4	5
1	2	3	4	5	Die Lagerbestände an Vorräten sind in meinem Werk groß	1	2	3	4	5

10. In welchem Umfang bietet Ihr Werk heute eine geringere oder größere Produktvielfalt als vor zehn Jahren?

- ☐ Heute weit geringere Produktvielfalt
- ☐ Etwas weniger
- ☐ Gleicher Stand
- ☐ Etwas mehr
- ☐ Heute weit größere Produktvielfalt

11. In welchem Umfang erwartet Ihr Werk, künftig geringere oder größere Produktvielfalt anzubieten?

- ☐ Künftig weit geringere Produktvielfalt
- ☐ Etwas weniger
- ☐ Gleicher Stand
- ☐ Etwas mehr
- ☐ Künftig weit größere Produktvielfalt

12. Bitte geben Sie die ungefähre durchschnittliche Lebenszyklusdauer der Produkte Ihres Werks an – bezogen auf heute und bezogen auf die Zeit vor zehn Jahren.

Heute: ☐ Jahre Vor zehn Jahren: ☐ Jahre

13. In welchem Umfang erwartet Ihr Werk künftig eine Zunahme oder Abnahme der durchschnittlichen Lebenszyklusdauer seiner Produkte?

- ☐ Künftig weit längerer Lebenszyklus
- ☐ Etwas länger
- ☐ Gleich lang
- ☐ Etwas kürzer
- ☐ Künftig weit kürzerer Lebenszyklus

14. Bitte geben Sie an, wie sich die Produktvielfalt auf die Handhabung folgender Aspekte auswirkt – bezogen auf heute und bezogen auf die Zeit vor zehn Jahren.

Zu jeder Aussage gibt es zwei Skalen: die **linke Skala** bezieht sich auf Ihre Wahrnehmung der **von Ihrem Werk gebotenen derzeitigen Produktvielfalt** und die **rechte Skala** bezieht sich auf Ihre Wahrnehmung der **Produktvielfalt, die Ihr Werk vor zehn Jahren bot**.

1 = Sehr leicht zu handhaben	Sehr leicht zu handhaben = 1
2 = Ziemlich leicht zu handhaben	Ziemlich leicht zu handhaben = 2
3 = Neutral	Neutral = 3
4 = Etwas schwer zu handhaben	Etwas schwer zu handhaben = 4
5 = Sehr schwer zu handhaben	Sehr schwer zu handhaben = 5

HEUTE		VOR 10 JAHREN
1 2 3 4 5	Qualität unserer Produkte	1 2 3 4 5
1 2 3 4 5	Qualität unserer Prozesse	1 2 3 4 5
1 2 3 4 5	Liefertreue meines Werks	1 2 3 4 5
1 2 3 4 5	Kosten meines Werks	1 2 3 4 5
1 2 3 4 5	Kosten unserer Endprodukte	1 2 3 4 5
1 2 3 4 5	Dauer unserer Produktentwicklungsprozesse	1 2 3 4 5
1 2 3 4 5	Mitarbeiterleistung meines Werks	1 2 3 4 5
1 2 3 4 5	Leistungsfähigkeit unserer Lieferanten	1 2 3 4 5
1 2 3 4 5	Zahl der Produktrückrufe durch mein Werk	1 2 3 4 5
1 2 3 4 5	Schwankungen in der Produktnachfrage	1 2 3 4 5
1 2 3 4 5	Zufriedenheit unserer Kunden	1 2 3 4 5
1 2 3 4 5	Zufriedenheit unserer Mitarbeiter	1 2 3 4 5
1 2 3 4 5	Wissensstand der Mitarbeiter	1 2 3 4 5
1 2 3 4 5	Für die Interaktion mit unseren Kunden erforderliche Zeit	1 2 3 4 5
1 2 3 4 5	Für die Interaktion mit unseren Lieferanten erforderliche Zeit	1 2 3 4 5

15. Bitte geben Sie an, wie sich die Lebenszyklusdauer Ihrer Produkte auf die Handhabung folgender Aspekte auswirkt – bezogen auf heute und bezogen auf die Zeit vor zehn Jahren.

Zu jeder Aussage gibt es zwei Skalen: die **linke Skala** bezieht sich auf Ihre Wahrnehmung der **derzeitigen Produktlebenszyklen in Ihrem Werk** und die **rechte Skala** bezieht sich auf Ihre Wahrnehmung der **Produktlebenszyklen in Ihrem Werk vor zehn Jahren**.

1 = Sehr leicht zu handhaben	Sehr leicht zu handhaben = 1
2 = Ziemlich leicht zu handhaben	Ziemlich leicht zu handhaben = 2
3 = Neutral	Neutral = 3
4 = Etwas schwer zu handhaben	Etwas schwer zu handhaben = 4
5 = Sehr schwer zu handhaben	Sehr schwer zu handhaben = 5

HEUTE		VOR 10 JAHREN
1 2 3 4 5	Qualität unserer Produkte	1 2 3 4 5
1 2 3 4 5	Qualität unserer Prozesse	1 2 3 4 5
1 2 3 4 5	Liefertreue meines Werks	1 2 3 4 5
1 2 3 4 5	Kosten meines Werks	1 2 3 4 5
1 2 3 4 5	Kosten unserer Endprodukte	1 2 3 4 5
1 2 3 4 5	Dauer unserer Produktentwicklungsprozesse	1 2 3 4 5
1 2 3 4 5	Mitarbeiterleistung meines Werks	1 2 3 4 5
1 2 3 4 5	Leistungsfähigkeit unserer Lieferanten	1 2 3 4 5
1 2 3 4 5	Zahl der Produktrückrufe durch mein Werk	1 2 3 4 5
1 2 3 4 5	Schwankungen in der Produktnachfrage	1 2 3 4 5
1 2 3 4 5	Zufriedenheit unserer Kunden	1 2 3 4 5
1 2 3 4 5	Zufriedenheit unserer Mitarbeiter	1 2 3 4 5
1 2 3 4 5	Wissensstand der Mitarbeiter	1 2 3 4 5
1 2 3 4 5	Für die Interaktion mit unseren Kunden erforderliche Zeit	1 2 3 4 5
1 2 3 4 5	Für die Interaktion mit unseren Lieferanten erforderliche Zeit	1 2 3 4 5

Qualitätsmanagement

16. Bitte geben Sie an, inwieweit Sie folgenden Aussagen über das Qualitätsmanagement in Ihrem Werk zustimmen – bezogen auf heute und bezogen auf die Zeit vor zehn Jahren

Zu jeder Aussage gibt es zwei Skalen: die **linke Skala** bezieht sich auf Ihre Wahrnehmung der **aktuellen Situation in Ihrem Werk** und die **rechte Skala** bezieht sich auf Ihre Wahrnehmung der **Situation, die in Ihrem Werk vor zehn Jahren herrschte**.

1 = überhaupt nicht einverstanden	überhaupt nicht einverstanden = 1
2 = teilweise nicht einverstanden	teilweise nicht einverstanden = 2
3 = unentschieden	unentschieden = 3
4 = teilweise einverstanden	teilweise einverstanden = 4
5 = vollständig einverstanden	vollständig einverstanden = 5

HEUTE		VOR 10 JAHREN
1 2 3 4 5	Die Qualität unserer Produkte ist hervorragend	1 2 3 4 5
1 2 3 4 5	Qualitätsprobleme sind prognostizierbar	1 2 3 4 5
1 2 3 4 5	Unsere Lieferanten bestimmen die Qualität unserer Endprodukte	1 2 3 4 5
1 2 3 4 5	Einwandfreie Leistung ist für das Überleben meines Werks wesentlich	1 2 3 4 5
1 2 3 4 5	Mein Werk hat Probleme damit, die Zahl der Fehler gering zu halten	1 2 3 4 5
1 2 3 4 5	Kunden sind mehr auf Kosten als auf Qualität fixiert	1 2 3 4 5
1 2 3 4 5	Kunden sind stärker auf Liefertreue als auf Qualität fixiert	1 2 3 4 5
1 2 3 4 5	Nach Auslieferung unserer Produkte an die Kunden ist mein Werk für auftretende Fehler nicht verantwortlich	1 2 3 4 5
1 2 3 4 5	Qualitätsmanagement ist für meinen Werk wichtig	1 2 3 4 5
1 2 3 4 5	Die fachliche Kompetenz unserer Qualitätsabteilung ist ausreichend	1 2 3 4 5
1 2 3 4 5	Das Rechnungswesen unserer Kunden hat großen Einfluss auf die Spezifikationen der von meinem Werk angebotenen Produkte	1 2 3 4 5
1 2 3 4 5	In meinem Werk wird Teamwork gefördert	1 2 3 4 5
1 2 3 4 5	Alle unsere Mitarbeiter haben klare Verbesserungsziele	1 2 3 4 5
1 2 3 4 5	Schulung unserer Mitarbeiter ist nötig, um mit Entwicklungen Schritt zu halten	1 2 3 4 5
1 2 3 4 5	Schulung unserer Lieferanten sehen wir als unsere Verantwortung	1 2 3 4 5
1 2 3 4 5	Schwankungen in der Kundennachfrage wirken sich negativ auf die Qualität unserer Produkte aus	1 2 3 4 5
1 2 3 4 5	Produkte/Prozesse, die für sie nicht von kritischer Bedeutung sind, werden von unseren Kunden outgesourct	1 2 3 4 5
1 2 3 4 5	Das Outsourcing von Teilen des Produktionsprozesses an Spezialisten ist wesentlich, um die Komplexität der Fertigung zu beherrschen	1 2 3 4 5
1 2 3 4 5	Es ist schwierig, die Ursache eines Produktfehlers bis zum Ursprung zurückzuverfolgen	1 2 3 4 5
1 2 3 4 5	In meinem Werk wird Qualität während des Produktionsprozesses gemessen	1 2 3 4 5
1 2 3 4 5	In meinem Werk wird Qualität am Ende des Produktionsprozesses gemessen	1 2 3 4 5
1 2 3 4 5	Qualitätsprobleme hängen häufig mit nichttechnischen/emotionalen Fragen zusammen	1 2 3 4 5

17. Bitte geben Sie an, inwieweit Sie folgenden Aussagen über die Qualitätsreife in Ihrem Werk zustimmen – bezogen auf heute und bezogen auf die Zeit vor zehn Jahren

Zu jeder Aussage gibt es zwei Skalen: die **linke Skala** bezieht sich auf Ihre Wahrnehmung der **aktuellen Situation in Ihrem Werk** und die **rechte Skala** bezieht sich auf Ihre Wahrnehmung der **Situation, die in Ihrem Werk vor zehn Jahren herrschte**.

1 = überhaupt nicht einverstanden	überhaupt nicht einverstanden = 1
2 = teilweise nicht einverstanden	teilweise nicht einverstanden = 2
3 = unentschieden	unentschieden = 3
4 = teilweise einverstanden	teilweise einverstanden = 4
5 = vollständig einverstanden	vollständig einverstanden = 5

HEUTE						VOR 10 JAHREN				
1	2	3	4	5	Wir wissen nicht, weshalb wir Probleme mit der Qualität haben	1	2	3	4	5
1	2	3	4	5	Wir fragen uns, ob es unvermeidbar ist, immer Probleme mit der Qualität zu haben	1	2	3	4	5
1	2	3	4	5	Wir identifizieren und lösen Probleme durch engagiertes Management und Qualitätsverbesserung	1	2	3	4	5
1	2	3	4	5	Fehlervermeidung ist routinemäßiger Bestandteil unserer Tätigkeit	1	2	3	4	5
1	2	3	4	5	Wir wissen, weshalb wir keine Probleme mit der Qualität haben	1	2	3	4	5

Steuerung durch das Management

18. Bitte geben Sie an, inwieweit Sie folgenden Aussagen über die Steuerung durch das Management in Ihrem Werk zustimmen – bezogen auf heute und bezogen auf die Zeit vor zehn Jahren

Zu jeder Aussage gibt es zwei Skalen: die **linke Skala** bezieht sich auf Ihre Wahrnehmung der **aktuellen Situation in Ihrem Werk** und die **rechte Skala** bezieht sich auf Ihre Wahrnehmung der **Situation, die in Ihrem Werk vor zehn Jahren herrschte**.

1 = überhaupt nicht einverstanden	überhaupt nicht einverstanden = 1
2 = teilweise nicht einverstanden	teilweise nicht einverstanden = 2
3 = unentschieden	unentschieden = 3
4 = teilweise einverstanden	teilweise einverstanden = 4
5 = vollständig einverstanden	vollständig einverstanden = 5

HEUTE						VOR 10 JAHREN				
1	2	3	4	5	Mein Werk kommuniziert seine Mission und Vision deutlich an die Mitarbeiter	1	2	3	4	5
1	2	3	4	5	Mein Werk hat einen klaren Verhaltenskodex für seine Mitarbeiter	1	2	3	4	5
1	2	3	4	5	Mein Werk verwendet Pläne und Budgets, die auf Abweichungen überwacht werden	1	2	3	4	5
1	2	3	4	5	Die Manager in meinem Werk bringen sich persönlich in Entscheidungen ihrer Mitarbeiter ein	1	2	3	4	5
1	2	3	4	5	Unsere Kunden unterstützen mein Werk im Falle von Qualitätsproblemen	1	2	3	4	5
1	2	3	4	5	Unsere Kunden auferlegen meinem Werk strikte Qualitätsziele	1	2	3	4	5
1	2	3	4	5	Qualitätsziele der Kunden nicht zu erreichen, hat für meinen Werk ernste Konsequenzen	1	2	3	4	5
1	2	3	4	5	Unsere Kunden machen deutlich, welche Qualität sie jetzt und in Zukunft erwarten	1	2	3	4	5
1	2	3	4	5	Unsere Kunden binden mein Werk frühzeitig in die Entwicklung neuer Produkte ein	1	2	3	4	5
1	2	3	4	5	In meinem Werk gelten klare Regeln für die Weitergabe von Unternehmensinformationen an Lieferanten	1	2	3	4	5
1	2	3	4	5	Verträge zwischen meinem Werk und seinen Kunden sind sehr detailliert	1	2	3	4	5

1	2	3	4	5	Moderne Computersysteme sind unerlässlich, um die Produktionsprozesse in meinem Werk zu überwachen	1	2	3	4	5
1	2	3	4	5	Unsere Kunden definieren genau, welche Aspekte eines Produkts mein Werk verändern darf und welche nicht	1	2	3	4	5
1	2	3	4	5	Bei den Mitarbeitern feste Arbeitsabläufe durchzusetzen hilft, die Qualität in meinem Werk zu verbessern	1	2	3	4	5
1	2	3	4	5	Die Übertragung von Verantwortung auf unsere Mitarbeiter ist eine wesentliche Voraussetzung für die Herstellung der Produktvielfalt, die unsere Kunden fordern	1	2	3	4	5
1	2	3	4	5	Unsere Mitarbeiter werden angeregt, an Schulungen teilzunehmen	1	2	3	4	5
1	2	3	4	5	Gemeinsame Schulungen zwischen meinem Werk und unseren Kunden werden genutzt, um Gedanken auszutauschen	1	2	3	4	5
1	2	3	4	5	Häufige Meetings zwischen verschiedenen Spezialisten in meinem Werk sind erforderlich, um Qualitätsprobleme zu lösen	1	2	3	4	5
1	2	3	4	5	Die Erfassung von Daten und deren Vergleich mit Spezifikationen sind für mein Werk bei der Problemlösung von wesentlicher Bedeutung	1	2	3	4	5
1	2	3	4	5	Computersysteme sind nötig, um Know-how über frühere Produkte zu speichern und es für neue Produkte wiederzuverwenden	1	2	3	4	5
1	2	3	4	5	Zur Verbesserung der Qualität unserer Produkte ist es für uns von wesentlicher Bedeutung eine langfristige Verbesserungsstrategie zu haben	1	2	3	4	5
1	2	3	4	5	Die Qualitätsstrategie in meinem Werk wird regelmäßig an die Mitarbeiter kommuniziert	1	2	3	4	5
1	2	3	4	5	Mein Werk hält sich an eine Reihe von Qualitätsprinzipien, die mit Kunden nicht verhandelbar sind	1	2	3	4	5
1	2	3	4	5	In meinem Werk sind Instrumente zur Qualitätsverbesserung stets mit konkreten Ergebnissen verknüpft	1	2	3	4	5
1	2	3	4	5	Die Systeme zur Qualitätskontrolle in meinem Werk sind flexibel genug, um mit plötzlichen Veränderungen der Kundenanforderungen zurechtzukommen	1	2	3	4	5
1	2	3	4	5	"Poka yoke" (Fehlervermeidungs-)Systeme sind erforderlich, um zu verhindern, dass Mitarbeiter Fehler machen	1	2	3	4	5
1	2	3	4	5	In der Strategie meines Werks sind Grenzen einer annehmbaren Produkt- und Servicequalität klar festgelegt	1	2	3	4	5
1	2	3	4	5	In meinem Werk gibt es funktionsübergreifende Teams	1	2	3	4	5
1	2	3	4	5	Trotz des Drucks, termingerecht zu liefern, werden in meinem Werk stets strenge Produktqualitätskontrollen durchgeführt	1	2	3	4	5
1	2	3	4	5	Vereinbarte Qualitätsniveaus können auch notfalls nicht aufgegeben werden	1	2	3	4	5
1	2	3	4	5	Mein Werk erklärt seinen Mitarbeitern klar und regelmäßig, dass Mängel jeder Art inakzeptabel sind	1	2	3	4	5

19. Bitte geben Sie an, wie sich folgende Leistungsindikatoren für Ihr Werk während der letzten zehn Jahre entwickelt haben

1 = Stark abgenommen
2 = Etwas abgenommen
3 = Gleich geblieben
4 = Etwas gestiegen
5 = Stark gestiegen

1	2	3	4	5	Betriebsgewinn
1	2	3	4	5	Kundenzufriedenheit
1	2	3	4	5	Produktionsvolumen
1	2	3	4	5	Effizienz
1	2	3	4	5	Fertigungsflexibilität

1	2	3	4	5	Betriebsauslastung
1	2	3	4	5	Fertigungskosten
1	2	3	4	5	Fehlerrate (Parts per Million)
1	2	3	4	5	Liefertreue
1	2	3	4	5	Rohmaterialvorräte
1	2	3	4	5	Unfertige Erzeugnisse
1	2	3	4	5	Fertigproduktbestand
1	2	3	4	5	Flächenbedarf

Vielen Dank für Ihre wertvolle Zeit!

Wenn Sie über die Ergebnisse der Studie informiert werden möchten, können Sie uns per Fax (+31 10 408 9169) oder per eMail (vaniwaarden@few.eur.nl) Ihre eMail-Adresse senden. Die Anonymität Ihrer Antworten ist damit sichergestellt.

Bitte senden Sie den Fragebogen im beigefügten Umschlag an folgende FREEPOST-Adresse (Porto zahlt Empfänger):

Erasmus University Rotterdam,
Tulay Varisli, Room H15-01
INTERNATIONAL FREEPOST
I.B.R.S. / C.C.R.I. Numéro 5187
NL-3000 VB Rotterdam
Niederlande

Nederlandse Samenvatting (Summary in Dutch)

Inleiding

In veel bedrijfstakken (bijv. auto's, elektronica en kleding) is de complexiteit en onvoorspelbaarheid van productieprocessen in de afgelopen jaren toegenomen als gevolg van de voortdurend toenemende variëteit aan producten en de steeds korter wordende product levenscycli. Tegenwoordig kunnen consumenten kiezen uit een enorme variëteit aan producten omdat fabrikanten hun producten in steeds meer uitvoeringen, kleuren, smaken en formaten op de markt brengen. Deze producten blijven in veel gevallen ook steeds korter op de markt omdat ze snel verouderen vanwege nieuwe trends en technieken.

De combinatie van een groot aantal product varianten en korte product levenscycli heeft gevolgen voor de beheersbaarheid van de productieprocessen in organisaties die met deze ontwikkelingen geconfronteerd worden. Managers moeten hun schaarse tijd en middelen over een groot aantal producten verdelen die ook nog eens voortdurend vernieuwd en aangepast moeten worden. Dit staat in schril contrast met het verleden, toen in deze organisaties veelal massa productie plaatsvond van één of slechts enkele producten die voor een lange tijd geproduceerd werden.

Het onderzoek in deze dissertatie is gericht op de effecten van toenemende product variëteit en korter wordende product levenscycli op kwaliteitsbeheersing. Bestaande systemen voor het managen van de kwaliteit van producten en processen richten zich gewoonlijk op drie invalshoeken:

1. Focus op de klant ('weet wat de klant wil')

2. Procesbeheersing ('maak wat gevraagd wordt')

3. Continue verbetering van producten en processen ('zorg dat klanten tevreden blijven')

De relevantie en effectiviteit van elk van deze drie invalshoeken wordt verondersteld te worden beïnvloed door het aantal product varianten en de lengte van de product levenscycli. Naarmate de variëteit van het productaanbod toeneemt, zal ook de variëteit in klantenwensen toenemen, omdat een meer heterogene klantengroep bediend wordt. Dit maakt het voor een organisatie moeilijker om een duidelijke klantfocus te ontwikkelen. Op vergelijkbare wijze wordt het voor een organisatie moeilijker om processen te beheersen en te verbeteren als product variëteit toeneemt en product levenscycli korter worden. Een groot aantal product varianten betekent dat een organisatie met een groot aantal verschillende processen te maken heeft en/of binnen één proces een grote diversiteit aan producten produceert. Beide situaties bemoeilijken de toepassing van (statistische) methodes voor procesbeheersing, omdat verschillende product varianten niet met elkaar te vergelijken zijn, en omdat de productievolumes van elk type product te laag zijn om kwantitatieve analyses op uit te kunnen voeren. De korter wordende product levenscycli verergeren deze problemen omdat er weinig tijd is om verbeteringen in de huidige producten door te voeren als deze op korte termijn vervangen worden door nieuwe producten. Daarbij is het de vraag of toekomstige producten kunnen profiteren van ideeën voor verbeteringen die gebaseerd zijn op de huidige producten, omdat zowel product als proces technologieën snel veranderen.

Deze veronderstellingen over de toepasbaarheid van bestaande kwaliteitsmanagement systemen in een dynamische en onvoorspelbare omgeving van hoge product variëteit en korte levenscycli, zijn in lijn met eerder gepubliceerde onderzoeken naar kwaliteitsmanagement. Deze onderzoeken concludeerden dat bestaande kwaliteitsmanagement systemen een hoge mate van routinematig werk en een hoge mate van voorspelbaarheid vereisen.

Theoretisch Kader

Om de veronderstelde invloed van ontwikkelingen in product variëteit en levenscycli op kwaliteitsmanagement te kunnen bestuderen, is een model nodig dat verschillen in kwaliteitsbeleid tussen organisaties kan verklaren vanuit verschillen in omgevingsfactoren. Echter, de in de praktijk meest gebruikte kwaliteitsmodellen, zoals de ISO standaarden en de verschillende kwaliteitsprijs modellen, houden nauwelijks rekening met omgevingsfactoren waarmee organisaties te maken hebben. Deze modellen schrijven een bepaald gedrag voor aan organisaties, ongeacht de specifieke kenmerken van elke organisatie. Recente onderzoeken concluderen dat zulke universele kwaliteitsmanagement systemen niet optimaal zijn en dat organisatiespecifieke omstandigheden een rol moeten spelen in het kwaliteitsbeleid. Het advies in deze onderzoeken is daarom dat onderzoekers moeten zoeken naar geschikte modellen buiten de kwaliteitsdiscipline.

Voor het onderzoek in deze dissertatie is gekozen voor het '*four levers of control*' model van Robert Simons. Dit is een model uit de management control literatuur dat onderscheid maakt tussen, aan de ene kant, simpele en stabiele omgevingen en, aan de andere kant, complexe en onvoorspelbare omgevingen. Deze eigenschap maakt dit model zeer geschikt om de effecten van toenemende product variëteit en korter wordende product levenscycli op management control systemen te bestuderen. Hoewel de focus in dit onderzoek specifiek op kwaliteitsmanagement systemen is, kan vanuit de literatuur worden beargumenteerd dat dergelijke kwaliteitsmanagement systemen in essentie management control systemen zijn, omdat ze gericht zijn op het beheersen van de kwaliteit van producten en processen.

Simons' control model maakt onderscheid tussen vier verschillende soorten van control systemen:

1. *Beliefs systems*. Deze worden gebruikt door het management om medewerkers te inspireren en te stimuleren om in overeenstemming met de missie en visie te handelen.

2. *Boundary systems*. Deze worden gebruikt door het management om de grenzen aan te geven waarbinnen gehandeld moet worden door medewerkers.

3. *Diagnostic control systems*. Deze worden gebruikt door het management om medewerkers te bewegen bepaalde doelen te bereiken, via prestatie meetsystemen die gekoppeld zijn aan beloningen.

4. *Interactive control systems*. Deze worden gebruikt door het management om het leren in organisaties te stimuleren en nieuwe ideeën tot bloei te brengen.

Deze vier soorten van control systemen zijn geen systemen op zichzelf, maar ze beschrijven de kenmerken van concrete control systemen. Dus elk control systeem kan onderverdeeld worden in één van de vier genoemde categorieën. Het model claimt daarbij dat een organisatie een mix van de vier verschillende soorten control systemen moet toepassen om de strategie van de organisatie te kunnen realiseren. Deze mix van soorten control systemen hangt af van verschillende factoren, waaronder de complexiteit en voorspelbaarheid van de markt waarin een organisatie opereert. Het model stelt dat in een simpele en voorspelbare markt een organisatie kan volstaan met een relatief sterke focus op de diagnostische control systemen, terwijl in een complexe en dynamische markt er meer nadruk op de interactieve control systemen gelegd moet worden. In termen van het onderzoek in deze dissertatie betekent dat dus dat in markten met weinig product varianten en lange levenscycli er meer gebruikt gemaakt zal worden van diagnostische control systemen, terwijl in markten met veel product varianten en korte levenscycli er meer gebruikt gemaakt zal moeten worden van interactieve control systemen.

Empirisch Onderzoek

Het empirische deel van het onderzoek bestaat uit kwalitatieve case studies bij twee autofabrikanten en een truck fabrikant, en uit een kwantitatief onderzoek door middel van een enquête die gehouden is onder West-Europese toeleveranciers in de automobiel industrie.

Om een aantal redenen is de automobiel industrie een geschikte sector om het empirische onderzoek uit te voeren:

1. De automobiel industrie speelt al jaren een belangrijke rol bij de ontwikkelingen binnen kwaliteitsmanagement (bijv. Toyota is een bekende koploper in het kwaliteitsdenken).

2. De product variëteit is de laatste jaren enorm toegenomen in de automobiel industrie en de product levenscycli zijn steeds korter geworden.

3. Als gevolg van de toegenomen product variëteit en kortere levenscycli zijn autofabrikanten actief op zoek naar mogelijkheden om met hun steeds complexere en dynamischere productieprocessen om te gaan. Recente ontwikkelingen van gedeelde autoplatformen en modulaire productieprocessen zijn hier voorbeelden van.

4. De huidige kwaliteitsmanagement systemen staan onder druk in de automobiel industrie, gezien het feit dat de laatste jaren record aantallen auto's door autofabrikanten naar de garage zijn teruggeroepen vanwege kwaliteitsproblemen.

In zowel de case studies als het enquête project, is het heden steeds met het verleden vergeleken, om te begrijpen welke ontwikkelingen er geweest zijn in termen van product variëteit en levenscycli, en hoe deze ontwikkelingen samenhangen met ontwikkelingen in kwaliteitsmanagement systemen.

De case studies zijn gehouden bij drie verschillende fabrikanten:

1. Een truck fabrikant die de laatste tien jaar slechts een geringe toename van het aantal product varianten en een geringe afname van de lengte van product levenscycli heeft meegemaakt.

2. Een fabrikant van kleine personen auto's die de laatste tien jaar een matige toename van het aantal product varianten en een sterke afname van de lengte van product levenscycli heeft meegemaakt.

3. Een fabrikant van luxe personen auto's die de laatste tien jaar een sterke toename van het aantal product varianten en een matige afname van de lengte van product levenscycli heeft meegemaakt.

Gezien deze omschrijvingen van elk van de cases, zijn de hypotheses op basis van het onderzoeksmodel dat de truck fabrikant met name gebruik maakt van diagnostische kwaliteitsmanagement systemen, terwijl de twee autofabrikanten de nadruk leggen op interactieve kwaliteitsmanagement systemen.

De hypotheses voor het enquête project zijn in lijn met de case studies, namelijk dat toeleveranciers die te maken hebben met een klein aantal product varianten en lange levenscycli de nadruk leggen op diagnostische kwaliteitsmanagement systemen, terwijl toeleveranciers die te maken hebben met een groot aantal product varianten en korte levenscycli de nadruk leggen op interactieve kwaliteitsmanagement systemen.

Resultaten

Uit de case studies is gebleken dat de toenemende product variëteit en korter wordende levenscycli een significante impact hebben op de productieprocessen in de auto industrie. De ontwikkelingen van de laatste jaren hebben geleid tot complexe productieprocessen die specifieke kennis vereisen die bij veel fabrikanten onvoldoende aanwezig is. Daarom zijn gespecialiseerde toeleveranciers steeds sterker betrokken bij de productie processen. Toeleveranciers produceren een steeds groter deel van de voertuigen en zijn ook onmisbaar voor de ontwikkeling van nieuwe voertuigen.

De resultaten van de case studies stemmen gedeeltelijk overeen met de opgestelde hypotheses. De truck fabrikant met zijn geringe toename van het aantal product varianten en geringe afname van de lengte van product levenscycli legt inderdaad de nadruk op diagnostische kwaliteitsmanagement systemen en maakt nauwelijks gebruik van interactieve kwaliteitsmanagement systemen. De fabrikant van kleine personen auto's met zijn matige toename van het aantal product varianten en sterke afname van de lengte van product levenscycli maakt veel gebruik van interactieve kwaliteitsmanagement systemen, zoals verondersteld op basis van het onderzoeksmodel. De fabrikant van luxe personen auto's met zijn sterke toename van het aantal product varianten en matige afname van de lengte van product levenscycli maakt gebruik van een gebalanceerde mix van diagnostische en interactieve kwaliteitsmanagement systemen. Dit laatste is niet in lijn met de hypotheses, want er was verondersteld dat de nadruk zou liggen op interactieve kwaliteitsmanagement systemen.

Deze uitkomsten van de case studies zijn meegenomen als input voor het enquête project onder toeleveranciers in de automobiel industrie. Er is dus door middel van de enquête expliciet gekeken naar de verschillen tussen de effecten van toenemende product variëteit en korter wordende product levenscycli op kwaliteitsmanagement systemen.

De toeleveranciers die de enquête ingevuld hebben, ervaren dezelfde ontwikkelingen als de drie case study bedrijven. Ook bij hen is over de laatste jaren de product variëteit toegenomen en zijn de levenscycli korter geworden. Deze ontwikkelingen hebben volgens deze toeleveranciers een significante invloed gehad op de prestaties van hun organisaties. De korter wordende product levenscycli hebben het bijvoorbeeld significant moeilijker gemaakt om de kwaliteit van zowel producten als processen te beheersen. Niettemin geven de toeleveranciers aan dat kwaliteitsmanagement nog even belangrijk voor hen is als tien jaar geleden. De reden dat toeleveranciers toch voortdurend blijven innoveren en frequent nieuwe producten blijven ontwikkelen, moet gezocht worden in hun relatie met de klant. Klanten vragen om een grote variëteit aan producten en om de laatste innovaties, maar belangrijker is waarschijnlijk dat de toekomst van de toeleveranciers afhangt van hun capaciteiten om nieuwe producten en varianten te ontwikkelen. De toeleveranciers die over de afgelopen tien jaar in staat zijn geweest om een veelheid aan nieuwe producten te ontwikkelen, hebben hun productie volumes en operationele winst zien stijgen. Terwijl toeleveranciers die niet in staat zijn geweest om voldoende nieuwe producten te ontwikkelen hun productie volumes en operationele winst juist zagen teruglopen.

De resultaten van het enquête onderzoek komen gedeeltelijk overeen met de hypotheses. Een sterkere nadruk op interactieve kwaliteitsmanagement systemen hangt wel samen met korter wordende product levenscycli, maar niet met toenemende product variëteit. Op basis van het onderzoeksmodel was verondersteld dat het gebruik van interactieve kwaliteitsmanagement systemen met beide ontwikkelingen samen zou hangen. Een geringere nadruk op diagnostische kwaliteitsmanagement systemen hangt noch met korter wordende levenscycli, noch met toenemende product variëteit samen, hoewel dit wel was verondersteld op basis van het onderzoeksmodel.

Conclusies

Op basis van de case studies en het enquête project kan worden geconcludeerd dat de ontwikkelingen in product variëteit en levenscycli verschillende vormen aan kunnen nemen. In deze dissertatie zijn zowel voor product variëteit als voor levenscycli drie schalen ontwikkeld (zie secties 8.2.2 en 8.2.3). De drie schalen voor product variëteit maken het mogelijk om verschillende vormen van product variëteit van elkaar te onderscheiden en de drie schalen voor levenscycli maken het mogelijk om verschillende soorten levenscycli van elkaar te onderscheiden.

Het onderzoek heeft ook duidelijk aangetoond dat omgevingsfactoren van invloed zijn op het kwaliteitsbeleid bij organisaties in de automobiel industrie. Het gebruikte onderzoeksmodel (Simons' *four levers of control model*) is geschikt gebleken voor toepassing binnen kwaliteitsmanagement, omdat het model inzichtelijk kan maken hoe omgevingsfactoren van invloed zijn op kwaliteitsmanagement.

Uit het onderzoek is gebleken dat in situaties van korter wordende product levenscycli het gebruik van interactieve kwaliteitsmanagement systemen toeneemt, zoals verondersteld op basis van het onderzoeksmodel. Echter, in situaties van toenemende product variëteit is de veronderstelde toename van interactieve kwaliteitsmanagement systemen niet gevonden. Dit is wellicht een indicatie van het verschil in impact op de organisatie tussen veranderingen in product variëteit en veranderingen in product levenscycli. Het introduceren van nieuwe varianten op bestaande producten is, vergeleken met het ontwikkelen van compleet nieuwe producten, relatief eenvoudig en goed te plannen. Daarom is het misschien niet nodig om meer gebruik te maken van interactieve kwaliteitsmanagement systemen in een situatie van toenemende product variëteit. Het ontwikkelen van compleet nieuwe producten is risicovol en onvoorspelbaar omdat het succes sterk beïnvloed wordt door technologische vooruitgang en activiteiten van concurrerende organisaties. In een dergelijke situatie zijn interactieve kwaliteitsmanagement systemen blijkbaar belangrijk.

In het gebruik van diagnostische kwaliteitsmanagement systemen zijn weinig verschuivingen waargenomen. Bij de autofabrikanten uit de case studies konden enkele ontwikkelingen waargenomen worden in het gebruik van diagnostische systemen, maar de enquête onder toeleveranciers heeft geen veranderingen aangegeven. Dit wordt wellicht veroorzaakt door het strikte gebruik van formele kwaliteitsnormen en systemen die, met name voor toeleveranciers, een verplichting zijn om zaken te kunnen doen in de automobiel industrie. Deze kwaliteitsnormen en systemen zijn overwegend diagnostisch van aard en worden altijd toegepast, ongeacht hun geschiktheid voor specifieke organisatorische omstandigheden. Dit kan misschien de zeer geringe variatie in het gebruik van diagnostische kwaliteitsmanagement systemen verklaren.

Toekomstverwachtingen voor Kwaliteitsmanagement

Op basis van het onderzoek in deze dissertatie kunnen een aantal verwachtingen voor de toekomst van kwaliteitsmanagement worden gegeven. Ten eerste is duidelijk geworden dat omgevingsfactoren een belangrijke invloed hebben op het kwaliteitsbeleid van organisaties. Deze invloed zal in de toekomst meer tot zijn recht moeten komen door kwaliteitsmanagement systemen beter af te stemmen op de specifieke organisatie die ze gebruikt. Echter, het is ook gebleken dat de impact van verschillende omgevingsfactoren op kwaliteitsmanagement varieert. Daarom is er een rol weggelegd voor onderzoekers om de relatie tussen omgevingsfactoren en kwaliteitsmanagement verder te bestuderen.

De tweede verwachting voor de toekomst van kwaliteitsmanagement is dat de nadruk meer zal komen te liggen op ketenmanagement. Toeleveranciers spelen een steeds grotere rol in de ontwikkeling en productie van bijvoorbeeld auto's. Hierdoor wordt hun invloed op de kwaliteit van het eindproduct ook steeds groter. De huidige veelgebruikte kwaliteitssystemen houden wel expliciet rekening met productieprocessen die uitbesteed worden aan leveranciers, maar het is de vraag in hoeverre ze in staat zijn om ook de kwaliteit van uitbestede ontwikkelprocessen te waarborgen.

De derde verwachting voor de toekomst van kwaliteitsmanagement is dat het belang van niet-technische kwaliteitsproblemen zal toenemen. Kwaliteitsmanagement systemen zijn goed in het traceren en corrigeren van technische gebreken. Echter, een toenemende bron van kwaliteitsproblemen ligt niet in de technische gebreken maar in gevoelens van teleurstelling bij de consument omdat het product niet overeenkomt met zijn/haar verwachtingen. Omdat er bij dergelijke problemen geen sprake is van een technisch defect, zijn ze niet oplosbaar door het product te repareren. Organisaties proberen daarom deze problemen te voorkomen. Het product ontwikkelproces speelt hierbij een belangrijke rol, omdat tijdens de ontwikkelfase de wensen van de klant leidend moeten zijn. Echter, als organisaties te maken hebben met een grote variëteit aan producten en daarbij met een grote variëteit aan klantwensen, zal het niet mogelijk zijn om aan de verwachtingen van elke klant te voldoen. Met als gevolg dat sommige klanten ontevreden zullen zijn met een product dat technisch in orde is. Dit zijn aspecten van kwaliteitsmanagement die tot nu toe weinig aandacht gekregen hebben, omdat er in de huidige systemen vanuit gegaan wordt dat alle problemen te voorkomen of op te lossen zijn.

About the author

Jos van Iwaarden (Reimerswaal, The Netherlands, 10 December 1978) obtained his MSc degree in business economics from Erasmus University Rotterdam, The Netherlands in June 2002. In September 2002 he started as PhD candidate at the Erasmus Research Institute of Management. During his PhD research, he has been a visiting research fellow at the Manchester Business School, UK. From September 2006 he has been appointed as assistant professor at the Management of Technology and Innovation department of RSM Erasmus University.

He published over fifteen papers about quality management and organisational improvement in international peer-reviewed journals, such as *International Journal of Quality and Reliability Management, Information and Management, Total Quality Management and Business Excellence, International Small Business Journal, Managing Service Quality, International Journal of Productivity and Quality Management,* and *The TQM Magazine*.

Since January 2006 he is Associate Quality Editor for the *International Journal of Quality and Reliability Management*.

Erasmus Research Institute of Management (ERIM)

ERIM Ph.D. Series

Research in Management

ERIM Electronic Series Portal: http://hdl.handle.net/1765/1

Alvarez, H.L., *Distributed CollaborativeLlearning Communities Enabled by Information Communication Technology*, Promotor: Prof. dr. K. Kumar, EPS-2006-080-LIS, ISBN 90-5892-112-3, http://hdl.handle.net/1765/

Appelman, J.H., *Governance of Global Interorganizational Tourism Networks: Changing Forms of Co-ordination between the Travel Agency and Aviation Sector*, Promotors: Prof. dr. F.M. Go & Prof. dr. B. Nooteboom, EPS-2004-036-MKT, ISBN 90-5892-060-7, http://hdl.handle.net/1765/1199

Berens, G., *Corporate Branding: The Development of Corporate Associations and their Influence on Stakeholder Reactions*, Promotor: Prof. dr. C. B. M. van Riel, EPS-2004-039-ORG, ISBN 90 –5892–065–8, http://hdl.handle.net/1765/1273

Berghe, D.A.F., *Working Across Borders: Multinational Enterprises and the Internationalization of Employment*, Promotors: Prof. dr. R.J.M. van Tulder & Prof. dr. E.J.J. Schenk, EPS-2003-029-ORG, ISBN 90-5892-05-34, http://hdl.handle.net/1765/1041

Bijman, W.J.J., *Essays on Agricultural Co-operatives: Governance Structure in Fruit and Vegetable Chains*, Promotor: Prof. dr. G.W.J. Hendrikse, EPS-2002-015-ORG, ISBN: 90-5892-024-0, http://hdl.handle.net/1765/867

Blindenbach-Driessen, F., *Innovation Management in Project-Based Firms*, Promotor: Prof. dr. S.L. van de Velde, EPS-2006-082-LIS, ISBN: 90-5892-110-7, http://hdl.handle.net/1765/

Boer, N.I., *Knowledge Sharing within Organizations: A situated and relational Perspective,* Promotor: Prof. dr. K. Kumar, EPS-2005-060-LIS, ISBN: 90-5892-086-0, http://hdl.handle.net/1765/6770

Boer, C.A., *Distributed Simulation in Industry,* Promotors: Prof. dr. A. de Bruin & Prof. dr. ir. A. Verbraeck, EPS-2005-065-LIS, ISBN: 90-5892-093-3, http://hdl.handle.net/1765/6925

Brito, M.P. de, *Managing Reverse Logistics or Reversing Logistics Management?* Promotors: Prof. dr. ir. R. Dekker & Prof. dr. M. B. M. de Koster, EPS-2004-035-LIS, ISBN: 90-5892-058-5, http://hdl.handle.net/1765/1132

Brohm, R., *Polycentric Order in Organizations: a dialogue between Michael Polanyi and IT-consultants on knowledge, morality, and organization, P*romotors: Prof. dr. G. W. J. Hendrikse & Prof. dr. H. K. Letiche, EPS-2005-063-ORG, ISBN: 90-5892-095-X, http://hdl.handle.net/1765/6911

Campbell, R.A.J., *Rethinking Risk in International Financial Markets*, Promotor: Prof. dr. C.G. Koedijk, EPS-2001-005-F&A, ISBN: 90-5892-008-9, http://hdl.handle.net/1765/306

Chen, Y., *Labour Flexibility in China's Companies: An Empirical Study*, Promotors: Prof. dr. A. Buitendam & Prof. dr. B. Krug, EPS-2001-006-ORG, ISBN: 90-5892-012-7, http://hdl.handle.net/1765/307

Daniševská, P., *Empirical Studies on Financial Intermediation and Corporate Policies*, Promotor: Prof. dr. C.G. Koedijk, EPS-2004-044-F&A, ISBN 90–5892–070–4, http://hdl.handle.net/1765/1518

Delporte-Vermeiren, D.J.E., *Improving the Flexibility and Profitability of ICT-enabled Business Networks: An Assessment Method and Tool*, Promotors: Prof.mr. dr. P.H.M. Vervest & Prof. dr. ir. H.W.G.M. van Heck, EPS-2003-020-LIS, ISBN: 90-5892-040-2, http://hdl.handle.net/1765/359

Dijksterhuis, M., *Organizational Dynamics of Cognition and Action in the Changing Dutch and US Banking Industries*, Promotors: Prof. dr. ir. F.A.J. van den Bosch & Prof. dr. H.W. Volberda, EPS-2003-026-STR, ISBN: 90-5892-048-8, http://hdl.handle.net/1765/1037

Fenema, P.C. van, *Coordination and Control of Globally Distributed Software Projects*, Promotor: Prof. dr. K. Kumar, EPS-2002-019-LIS, ISBN: 90-5892-030-5, http://hdl.handle.net/1765/360

Fleischmann, M., *Quantitative Models for Reverse Logistics*, Promoters: Prof. dr. ir. J.A.E.E. van Nunen & Prof. dr. ir. R. Dekker, EPS-2000-002-LIS, ISBN: 35-4041-711-7, http://hdl.handle.net/1765/1044

Flier, B., *Strategic Renewal of European Financial Incumbents: Coevolution of Environmental Selection, Institutional Effects, and Managerial Intentionality*, Promotors: Prof. dr. ir. F.A.J. van den Bosch & Prof. dr. H.W. Volberda, EPS-2003-033-STR, ISBN: 90–5892–055–0, http://hdl.handle.net/1765/1071

Fok, D., *Advanced Econometric Marketing Models*, Promotor: Prof. dr. P.H.B.F. Franses, EPS-2003-027-MKT, ISBN: 90-5892-049-6, http://hdl.handle.net/1765/1035

Ganzaroli , A., *Creating Trust between Local and Global Systems*, Promotors: Prof. dr. K. Kumar & Prof. dr. R.M. Lee, EPS-2002-018-LIS, ISBN: 90-5892-031-3, http://hdl.handle.net/1765/361

Gilsing, V.A., *Exploration, Exploitation and Co-evolution in Innovation Networks*, Promotors: Prof. dr. B. Nooteboom & Prof. dr. J.P.M. Groenewegen, EPS-2003-032-ORG, ISBN 90-5892-054-2, http://hdl.handle.net/1765/1040

Govers, R., *Virtual Tourism Destination Image: Glocal identities constructed, perceived and experienced*, Promotors: Prof. dr. F.M. Go & Prof. dr. K. Kumar, EPS-2005-069-MKT, ISBN 90-5892-107-7, http://hdl.handle.net/1765/6981

Graaf, G. de, *Tractable Morality: Customer Discourses of Bankers, Veterinarians and Charity Workers*, Promotors: Prof. dr. F. Leijnse & Prof. dr. T. van Willigenburg, EPS-2003-031-ORG, ISBN: 90–5892–051–8, http://hdl.handle.net/1765/1038

Hagemeijer, R.E., *The Unmasking of the Other*, Promotors: Prof. dr. S.J. Magala, Prof. dr. H.K. Letiche, EPS-2005-068-ORG, ISBN: 90–5892–097–6, http://hdl.handle.net/1765/6963

Hartigh, E. den, *Increasing Returns and Firm Performance: An Empirical Study*, Promotor: Prof. dr. H.R. Commandeur, EPS-2005-067-STR, ISBN: 90–5892–098–4, http://hdl.handle.net/1765/6939

Hermans. J.M., *ICT in Information Services, Use and deployment of the Dutch securities trade, 1860-1970.* Promotor: Prof. dr. drs. F.H.A. Janszen, EPS-2004-046-ORG, ISBN 90-5892-072-0, http://hdl.handle.net/1765/1793

Heugens, P.M.A.R., *Strategic Issues Management: Implications for Corporate Performance*, Promotors: Prof. dr. ir. F.A.J. van den Bosch & Prof. dr. C.B.M. van Riel, EPS-2001-007-STR, ISBN: 90-5892-009-7, http://hdl.handle.net/1765/358

Hooghiemstra, R., *The Construction of Reality*, Promotors: Prof. dr. L.G. van der Tas RA & Prof. dr. A.Th.H. Pruyn, EPS-2003-025-F&A, ISBN: 90-5892-047-X, http://hdl.handle.net/1765/871

Iastrebova, K, *Manager's Information Overload: The Impact of Coping Strategies on Decision-Making Performance*, Promotor: Prof. dr. H.G. van Dissel, EPS-2006-077-LIS, ISBN 90-5892-111-5, http://hdl.handle.net/1765/

Jansen, J.J.P., *Ambidextrous Organizations*, Promotors: Prof. dr. ir. F.A.J. Van den Bosch & Prof. dr. H.W. Volberda, EPS-2005-055-STR, ISBN 90-5892-081-X, http://hdl.handle.net/1765/

Jong, C. de, *Dealing with Derivatives: Studies on the Role, Informational Content and Pricing of Financial Derivatives*, Promotor: Prof. dr. C.G. Koedijk, EPS-2003-023-F&A, ISBN: 90-5892-043-7, http://hdl.handle.net/1765/1043

Keizer, A.B., *The Changing Logic of Japanese Employment Practices: A Firm-Level Analysis of Four Industries.* Promotors: Prof. dr. J.A. Stam & Prof. dr. J.P.M. Groenewegen, EPS-2005-057-ORG, ISBN: 90-5892-087-9, http://hdl.handle.net/1765/6667

Kippers, J., *Empirical Studies on Cash Payments*, Promotor: Prof. dr. Ph.H.B.F. Franses, EPS-2004-043-F&A. ISBN 90-5892-069-0, http://hdl.handle.net/1765/1520

Kole, E., *On Crises, Crashes and Comovements*, Promotors: Prof. dr. C.G. Koedijk & Prof. dr. J.C.M. Verbeek, EPS-2006-083-F&A. ISBN 90-5892-114-X, http://hdl.handle.net/1765/

Koppius, O.R., *Information Architecture and Electronic Market Performance*, Promotors: Prof. dr. P.H.M. Vervest & Prof. dr. ir. H.W.G.M. van Heck, EPS-2002-013-LIS, ISBN: 90-5892-023-2, http://hdl.handle.net/1765/921

Kotlarsky, J., *Management of Globally Distributed Component-Based Software Development Projects,* Promotor: Prof. dr. K. Kumar, EPS-2005-059-LIS, ISBN: 90-5892-088-7, http://hdl.handle.net/1765/6772

Kuilman, J., *The re-emergence of foreign banks in Shanghai: An ecological analysis,* Promotor: Prof. dr. B. Krug, EPS-2005-066-ORG, ISBN: 90-5892-096-8, http://hdl.handle.net/1765/6926

Langen, P.W. de, *The Performance of Seaport Clusters: A Framework to Analyze Cluster Performance and an Application to the Seaport Clusters of Durban, Rotterdam and the Lower Mississippi*, Promotors: Prof. dr. B. Nooteboom & Prof. drs. H.W.H. Welters, EPS-2004-034-LIS, ISBN: 90-5892-056-9, http://hdl.handle.net/1765/1133

Le Anh, T., *Intelligent Control of Vehicle-Based Internal Transport Systems*, Promotors: Prof. dr. M.B.M. de Koster & Prof. dr. ir. R. Dekker, EPS-2005-051-LIS, ISBN 90-5892-079-8, http://hdl.handle.net/1765/6554

Le-Duc, T., *Design and control of efficient order picking processes*, Promotor: Prof. dr. M.B.M. de Koster, EPS-2005-064-LIS, ISBN 90-5892-094-1, http://hdl.handle.net/1765/6910

Lentink, R.M., *Algorithmic Decision Support for Shunt Planning*, Promotors: Prof. dr. L.G. Kroon & Prof. dr. ir. J.A.E.E. van Nunen, EPS-2006-073-LIS, ISBN 90-5892-104-2, http://hdl.handle.net/1765/

Liang, G., *New Competition: Foreign Direct Investment And Industrial Development In China,* Promotor: Prof. dr. R.J.M. van Tulder, EPS-2004-047-ORG, ISBN 90–5892–073–9, http://hdl.handle.net/1765/1795

Loef, J., *Incongruity between Ads and Consumer Expectations of Advertising*, Promotors: Prof. dr. W.F. van Raaij & Prof. dr. G. Antonides, EPS-2002-017-MKT, ISBN: 90-5892-028-3, http://hdl.handle.net/1765/869

Londoño, M. del Pilar, *Institutional Arrangements that Affect Free Trade Agreements: Economic Rationality Versus Interest Groups*, Promotors: Prof. dr. H.E. Haralambides & Prof. dr. J.F. Francois, EPS-2006-078-LIS, ISBN: 90-5892-108-5, http://hdl.handle.net/1765

Maeseneire, W., de, *Essays on Firm Valuation and Value Appropriation,* Promotor: Prof. dr. J.T.J. Smit, EPS-2005-053-F&A, ISBN 90-5892-082-8,

Mandele, L.M., van der, *Leadership and the Inflection Point: A Longitudinal Perspective*, Promotors: Prof. dr. H.W. Volberda, Prof. dr. H.R. Commandeur, EPS-2004-042-STR, ISBN 90–5892–067–4, http://hdl.handle.net/1765/1302

Meer, J.R. van der, *Operational Control of Internal Transport*, Promotors: Prof. dr. M.B.M. de Koster & Prof. dr. ir. R. Dekker, EPS-2000-001-LIS, ISBN: 90-5892-004-6, http://hdl.handle.net/1765/859

Mentink, A., *Essays on Corporate Bonds*, Promotor: Prof. dr. A.C.F. Vorst, EPS-2005-070-F&A, ISBN: 90-5892-100-X, http://hdl.handle.net/1765/7121

Miltenburg, P.R., *Effects of Modular Sourcing on Manufacturing Flexibility in the Automotive Industry: A Study among German OEMs*, Promotors: Prof. dr. J. Paauwe & Prof. dr. H.R. Commandeur, EPS-2003-030-ORG, ISBN: 90-5892-052-6, http://hdl.handle.net/1765/1039

Moerman, G.A., *EmpiricalStudies on Asset Pricing and Banking in the Euro Area,* Promotors: Prof. dr. C.G. Koedijk, EPS-2005-058-F&A, ISBN: 90-5892-090-9, http://hdl.handle.net/1765/6666

Mol, M.M., *Outsourcing, Supplier-relations and Internationalisation: Global Source Strategy as a Chinese Puzzle*, Promotor: Prof. dr. R.J.M. van Tulder, EPS-2001-010-ORG, ISBN: 90-5892-014-3, http://hdl.handle.net/1765/355

Mulder, A., *Government Dilemmas in the Private Provision of Public Goods*, Promotor: Prof. dr. R.J.M. van Tulder, EPS-2004-045-ORG, ISBN: 90-5892-071-2, http://hdl.handle.net/1765

Muller, A.R., *The Rise of Regionalism: Core Company Strategies Under The Second Wave of Integration*, Promotor: Prof. dr. R.J.M. van Tulder, EPS-2004-038-ORG, ISBN 90–5892–062–3, http://hdl.handle.net/1765/1272

Oosterhout, J., van, *The Quest for Legitimacy: On Authority and Responsibility in Governance*, Promotors: Prof. dr. T. van Willigenburg & Prof.mr. H.R. van Gunsteren, EPS-2002-012-ORG, ISBN: 90-5892-022-4, http://hdl.handle.net/1765/362

Pak, K., *Revenue Management: New Features and Models*, Promotor: Prof. dr. ir. R. Dekker, EPS-2005-061-LIS, ISBN: 90-5892-092-5,

Peeters, L.W.P., *Cyclic Railway Timetable Optimization*, Promotors: Prof. dr. L.G. Kroon & Prof. dr. ir. J.A.E.E. van Nunen, EPS-2003-022-LIS, ISBN: 90-5892-042-9, http://hdl.handle.net/1765/429

Pietersz, R., *Pricing Models for Bermudan-style Interest Rate Derivatives*, Promotors: Prof. dr. A.A.J. Pelsser & Prof. dr. A.C.F. Vorst, EPS-2005-071- F&A, ISBN 90-5892-099-2, http://hdl.handle.net/1765/7122

Popova, V., *Knowledge Discovery and Monotonicity*, Promotor: Prof. dr. A. de Bruin, EPS-2004-037-LIS, ISBN 90-5892-061-5, http://hdl.handle.net/1765/1201

Pouchkarev, I., *Performance Evaluation of Constrained Portfolios*, Promotors: Prof. dr. J. Spronk & Dr. W.G.P.M. Hallerbach, EPS-2005-052-F&A, ISBN 90-5892-083-6, http://hdl.handle.net/1765/6731

Puvanasvari Ratnasingam, P., *Interorganizational Trust in Business to Business E-Commerce*, Promotors: Prof. dr. K. Kumar & Prof. dr. H.G. van Dissel, EPS-2001-009-LIS, ISBN: 90-5892-017-8, http://hdl.handle.net/1765/356

Romero Morales, D., *Optimization Problems in Supply Chain Management*, Promotors: Prof. dr. ir. J.A.E.E. van Nunen & Dr. H.E. Romeijn, EPS-2000-003-LIS, ISBN: 90-9014078-6, http://hdl.handle.net/1765/865

Roodbergen , K.J., *Layout and Routing Methods for Warehouses*, Promotors: Prof. dr. M.B.M. de Koster & Prof. dr. ir. J.A.E.E. van Nunen, EPS-2001-004-LIS, ISBN: 90-5892-005-4, http://hdl.handle.net/1765/861

Schweizer, T.S., *An Individual Psychology of Novelty-Seeking, Creativity and Innovation,* Promotor: Prof. dr. R.J.M. van Tulder. EPS-2004-048-ORG, ISBN: 90-5892-07-71, http://hdl.handle.net/1765/1818

Six, F.E., *Trust and Trouble: Building Interpersonal Trust Within Organizations*, Promotors: Prof. dr. B. Nooteboom & Prof. dr. A.M. Sorge, EPS-2004-040-ORG, ISBN 90–5892–064–X, http://hdl.handle.net/1765/1271

Slager, A.M.H., *Banking across Borders*, Promotors: Prof. dr. D.M.N. van Wensveen & Prof. dr. R.J.M. van Tulder, EPS-2004-041-ORG, ISBN 90-5892-066–6, http://hdl.handle.net/1765/1301

Sloot, L., *Understanding Consumer Reactions to Assortment Unavailability*, Promotors: Prof. dr. H.R. Commandeur , Prof. dr. E. Peelen & Prof. dr. P.C. Verhoef, EPS-2006-074-MKT, ISBN 90-5892-102–6, http://hdl.handle.net/1765/

Smit, W., *Market Information Sharing in Channel Relationships: Its Nature, Antecedents and Consequences*, Promotors: Prof. dr. H.R. Commandeur , Prof. dr. ir. G.H. van Bruggen & Prof. dr. ir. B. Wierenga, EPS-2006-076-MKT, ISBN 90-5892-106-9, http://hdl.handle.net/1765/

Speklé, R.F., *Beyond Generics: A closer look at Hybrid and Hierarchical Governance,* Promotor: Prof. dr. M.A. van Hoepen RA, EPS-2001-008-F&A, ISBN: 90-5892-011-9, http://hdl.handle.net/1765/357

Teunter, L.H., *Analysis of Sales Promotion Effects on Household Purchase Behavior*, Promotors: Prof. dr. ir. B. Wierenga & Prof. dr. T. Kloek, EPS-2002-016-ORG, ISBN: 90-5892-029-1, http://hdl.handle.net/1765/868

Valck, K. de, *Virtual Communities of Consumption: Networks of Consumer Knowledge and Companionship*, Promotors: Prof. dr. ir. G.H. van Bruggen, & Prof. dr. ir. B. Wierenga, EPS-2005-050-MKT, ISBN 90-5892-078-X, http://hdl.handle.net/1765/6663

Verheul, I., *Is there a (fe)male approach? Understanding gender differences in entrepreneurship*, Prof. dr. A.R. Thurik, EPS-2005-054-ORG, ISBN 90-5892-080-1, http://hdl.handle.net/1765/2005

Vis, I.F.A., *Planning and Control Concepts for Material Handling Systems*, Promotors: Prof. dr. M.B.M. de Koster & Prof. dr. ir. R. Dekker, EPS-2002-014-LIS, ISBN: 90-5892-021-6, http://hdl.handle.net/1765/866

Vlaar, P.W.L., *Making Sense of Formalization in Interorganizational Relationships: Beyond Coordination and Control,* Promotors: Prof. dr. ir. F.A.J. Van den Bosch & Prof. dr. H.W. Volberda, EPS-2006-075-STR, ISBN 90-5892-103-4, http://hdl.handle.net/1765

Vliet, P. van, *Downside Risk and Empirical Asset Pricing*, Promotor: Prof. dr. G.T. Post, EPS-2004-049-F&A ISBN 90-5892-07-55, http://hdl.handle.net/1765/1819

Vries-van Ketel E. de, *How Assortment Variety Affects Assortment Attractiveness: A Consumer Perspective*, Promotors: Prof. dr. G.H. van Bruggen, Prof.dr.ir. A.Smidts, EPS-2006-072-MKT, ISBN 90-5892-101-8, http://hdl.handle.net/1765/

Vromans, M.J.C.M., *Reliability of Railway Systems*, Promotors: Prof. dr. L.G. Kroon, Prof. dr. ir. R. Dekker & Prof. dr. ir. J.A.E.E. van Nunen, EPS-2005-062-LIS, ISBN: 90-5892-089-5, http://hdl.handle.net/1765/6773

Waal, T. de, *Processing of Erroneous and Unsafe Data*, Promotor: Prof. dr. ir. R. Dekker, EPS-2003-024-LIS, ISBN: 90-5892-045-3, http://hdl.handle.net/1765/870

Wielemaker, M.W., *Managing Initiatives: A Synthesis of the Conditioning and Knowledge-Creating View*, Promotors: Prof. dr. H.W. Volberda & Prof. dr. C.W.F. Baden-Fuller, EPS-2003-28-STR, ISBN 90-5892-050-X, http://hdl.handle.net/1765/1036

Wijk, R.A.J.L. van, *Organizing Knowledge in Internal Networks: A Multilevel Study*, Promotor: Prof. dr. ir. F.A.J. van den Bosch, EPS-2003-021-STR, ISBN: 90-5892-039-9, http://hdl.handle.net/1765/347

Wolters, M.J.J., *The Business of Modularity and the Modularity of Business*, Promotors: Prof. mr. dr. P.H.M. Vervest & Prof. dr. ir. H.W.G.M. van Heck, EPS-2002-011-LIS, ISBN: 90-5892-020-8, http://hdl.handle.net/1765/920

Changing Quality Controls

The effects of increasing product variety and shortening product life cycles

Management control systems, such as quality controls, are an essential part of any organisation. Yet, many such systems were originally developed when the business world was relatively stable. Currently, the rate of change in many markets is rapid because a large number of product variants are offered to consumers, and product life cycles are decreasing fast. This research is a study of how these two trends of increasing product variety and shortening product life cycles affect quality management systems.

Since the automotive industry is a business sector that has been strongly influenced by these two developments, the empirical part of the research consists of case studies at two car manufacturers and a truck manufacturer, and a questionnaire survey among a sample of Western European automotive suppliers. This research takes a novel approach to quality management research by applying a model from the field of management control.

The research has found that the complexity that is caused by increasing product variety and shortening product life cycles is to a large extent shifted to suppliers when car manufacturers outsource large parts of the development and assembly work. However, since Just-In-Time production is the standard for first tier suppliers, there is virtually no time to solve quality problems once they occur. Therefore, both car manufacturers and their suppliers have moved the focus of their quality management systems to preventing quality problems from occurring. In situations of shortening product life cycles, the empirical data clearly support the increased use of participative and cooperative quality control systems, as predicted by the research model.

Finally, the research suggests that the complexities of dealing simultaneously with many different product variants, combined with the frequent introduction of new products and variants, may mean that some quality problems are neither preventable, nor curable. Quality management research has to devise tools and techniques to enable the customer and the organisation to deal with these issues.

ERIM

The Erasmus Research Institute of Management (ERIM) is the Research School (Onderzoekschool) in the field of management of the Erasmus University Rotterdam. The founding participants of ERIM are RSM Erasmus University and the Erasmus School of Economics. ERIM was founded in 1999 and is officially accredited by the Royal Netherlands Academy of Arts and Sciences (KNAW). The research undertaken by ERIM is focussed on the management of the firm in its environment, its intra- and inter-firm relations, and its business processes in their interdependent connections.

The objective of ERIM is to carry out first rate research in management, and to offer an advanced graduate program in Research in Management. Within ERIM, over two hundred senior researchers and Ph.D. candidates are active in the different research programs. From a variety of academic backgrounds and expertises, the ERIM community is united in striving for excellence and working at the forefront of creating new business knowledge.

ERASMUS RESEARCH INSTITUTE OF MANAGEMENT

www.erim.eur.nl

ISBN 90-5892-117-4

Design: B&T Ontwerp en advies www.b-en-t.nl Print: Haveka www.haveka.nl