MASTER

Flexibility at the production company

how demand activated manufacturing, allows customers' requirements to be fulfilled better, by mass customising products

Potting, H.E.J.

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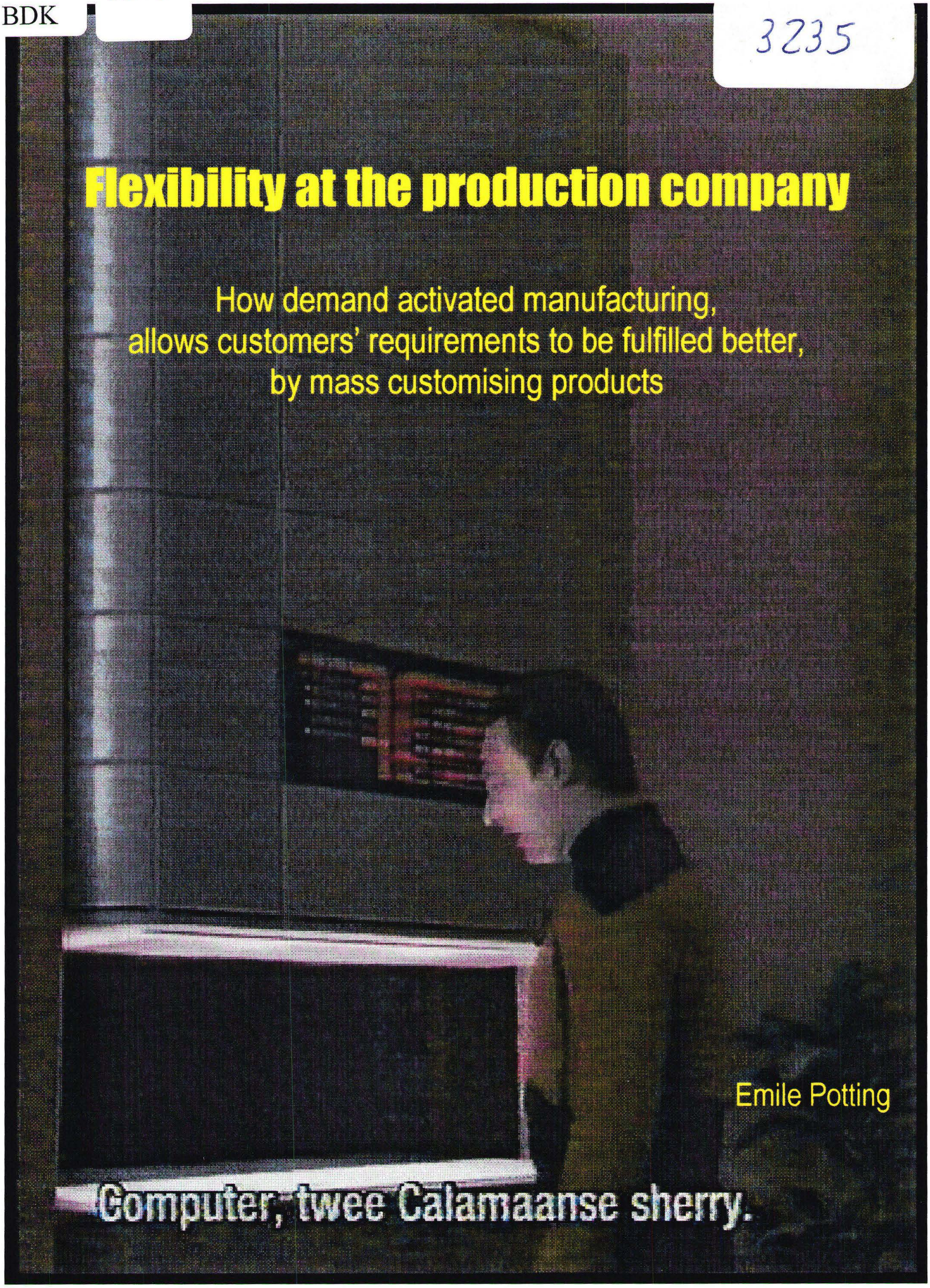
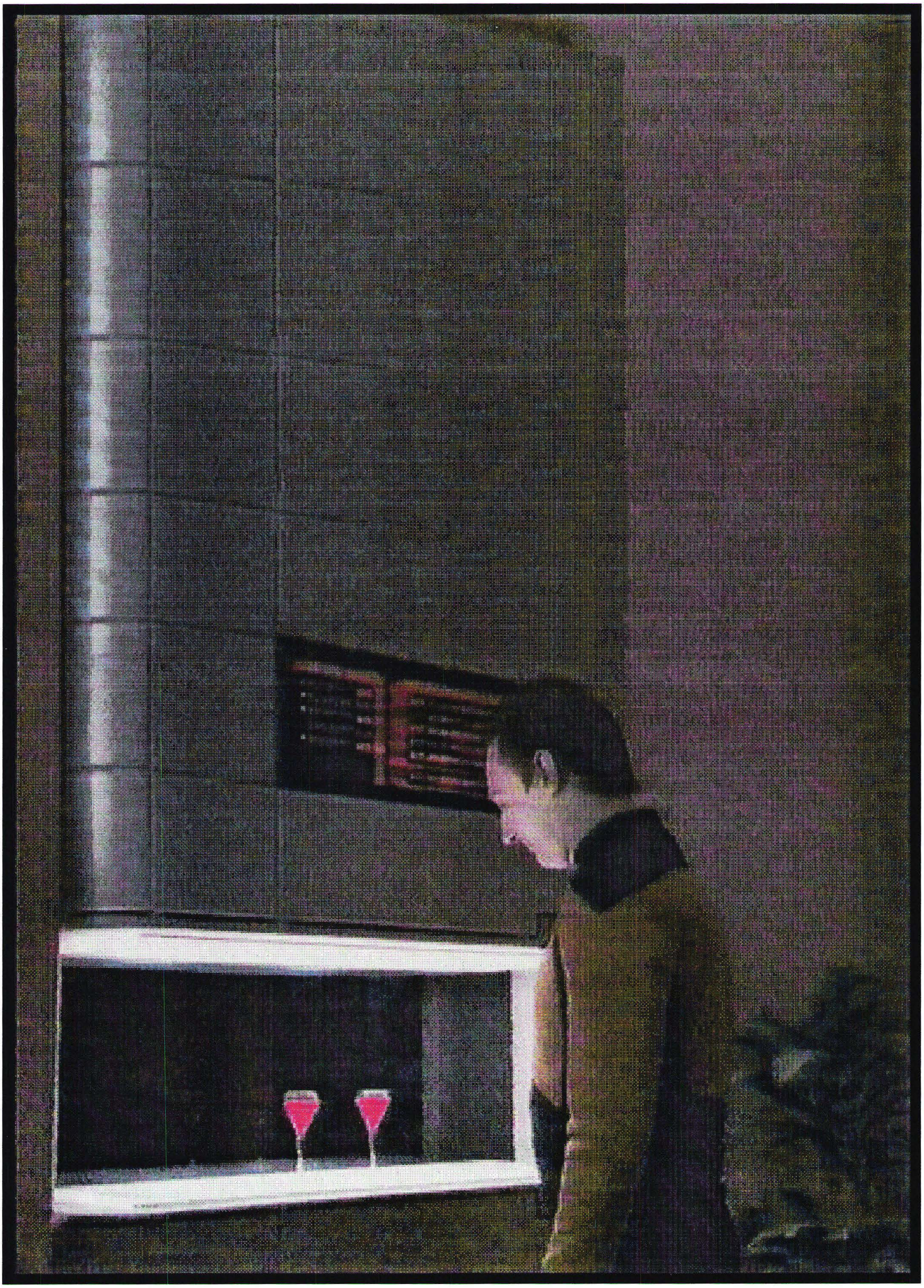


Emile Potting



Front, and following page: Two fragments of the series Star Trek. The New Generation actor is requesting two 'Calamaanse sherry' from the ship's computer, to have them manufactured and available immediately. The ability to move along the manufacturing process at such pace, is the real-world goal of mass customising agile manufacturers.

People, calling this Star Trek utopia total nonsense, especially when also agreeing the statements below, should definetely read this report carefully!

Mass-produced clothing will always be cheaper than clothing produced on an individual basis. (Johnson [g]).

New technology is not developed for each project. More often it is a matter of cleverly combining existing elements. Real custom work is far to costly. It's like saying 'I need a car with such and such specifications, and I will have it made to order.' That is out of the question. (H. Keizer, director of Philips Sales Organisation, supplying complete systems for furnishing buildings (Mastenbroek [44])).

Flexibility at the production company

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Principals: -Philips N.V.
Business Group; Sound & Vision, Television Eindhoven
Department; Advanced Systems Applications Labs, New Business Development

-Eindhoven University of Technology
Faculty; Technology Management
Department; Industrial Engineering
Trade group; Operations Research & Statistics

Tutors: -Drs. R.L.C. de Vaan
Philips N.V.
Business Group; Sound & Vision, Television Eindhoven
Department; Advanced Systems Applications Labs, New Business Development

-Ir. J. Daams
Eindhoven University of Technology
Faculty; Technology Management
Department; Industrial Engineering
Trade group; Manufacturing Technology

-Prof. Dr. H. G. Boddendijk
Managing director, Frits Philips Institute for Quality Management
Eindhoven University of Technology

-Dr. Ir. Ing. A.P. Nagel
Eindhoven University of Technology
Faculty; Technology Management
Department; Industrial Engineering
Trade group; Organisation & Management

Author: H.E.J. Potting
Student; Eindhoven University of Technology
Faculty; Technology Management
Department; Technical Engineering
Trade group; Operations Research & Statistics

Eindhoven, August 1997

Abstract

Customer requirements become tougher and tougher in today's mature buyers' markets. In order to still be able to distinguish from competitors, it will even be necessary to manufacture products to the specific needs of each individual customer. This demands a dramatic increase in overall flexibility of mass producing companies, like many parts of Philips, active in these dynamic markets. It will be discussed and explained that extremely flexible systems, capable of even mass customising products, can outperform Mass Production systems in these dynamic markets. The report indicates which course should be taken by Philips in becoming such a flexible mass customiser.

Preface

After having spent a whole year at the New Business Development department of the Philips ASA Lab, for me the apparently impossible task to describe and thank the extremely peculiar persons I dealt with during this period, in just a few lines. A person like Rob de Vaan for instance, who is capable of turning any petty question into an astonishing, educational lecture. Providing more useful, and interesting information than I have ever experienced at any lecture I have followed during my study. Although not really accelerating my assignment, a fantastic experience I would definitely not have liked to miss.

Characteristic of working at this department with Rob, is the fact that his students are given a lot of freedom. Where normally, assignments are present, here it took even months to actually find a graduate proposal! But as this freedom drove me almost to insanity at the beginning, it offered me the opportunity of choosing this interesting subject, and carrying out this assignment exactly as I wanted, later on. A unique opportunity, I think, yet impossible without the co-operation of the university. Therefore, thanks to Jo Daams, allowing, even stimulating me in using this freedom. Like Rob, also a very peculiar person, and also very pleasant working with. Hans Kleine, and colleague Marie Louise Gast, thank you for providing me very useful feedback, when needed most.
Also thanks to: Arie Nagel, and Henk Boddendijk for judging my report. Maarten van de Ven of Tulip, for giving me the opportunity of verifying my theories in a company, actually practising the principle of Mass Customisation. Ton van den Berg and the AIM team, for possibly really implementing the principle of Mass Customisation at Philips. My fellow graduate students, Michael, Tamar, Margôt, Henk, Dolf, and Matthijs. Wim, for providing me the Star Trek video. And my girlfriend Judith, and not just for having lend me her English dictionary.
I just want to thank everyone, who helped to make this period such a fantastic, and extremely educational experience. Although the current problems within Philips work pretty delaying actually, I recommend all students to try to obtain the same opportunity as I had.

Specifically, I want to thank all those friends, relatives and acquaintances, for giving me the essential joy and support in completing my study, despite the losses, and adversities within my family during this period. Also my father for having contributed to the actualisation of the person who I am now. As well as my big (despite being much smaller) brother. Of whom I know that he has been eager to assist me by word and deed, but who's not capable anymore unfortunately. Which must be very frustrating to him. Yet, he may look back at a past in which he has done so already multiply, and greatly!

Emile Potting.

Summary

Radios, televisions, textiles, shoes, automobiles and a host of other goods have entered the mature stage of its life cycle. Its production processes are for purchase by all comers. Therefore, competition could increase dramatically. But as products get more mature, more and more features have to be accounted for, in order to attain the same level of perceived quality. Markets are segmented by these mass producers, in order to try to meet different customer wants and needs better.
But traditional mass producers concentrate to much on technical quality of products. The definitions used by these mass producers, do not account for *individual* differences in customer wants and needs. In today's highly dynamic markets, their products will not satisfy all potential customers (to the same extent). Not even when segmenting markets to a high degree. Quality as perceived by the end-user, also implies the extent to what a product satisfies a customer, exactly the kind of product or service each customer wants, in the right amount, at the right time, and for the right price. Quality is only then perceived to be perfect, if products are tailored to the individual requirements of end-users.

Customers will only accept products deviating from being qualitatively perfect (as perceived by them), if there's no alternative. When one manufacturer is producing customised products, products of mass producing rivals will be perceived as qualitatively poor. Their technical perfect products, not capable of fulfilling individual customer desires, should actually be considered as waste! In calculating cost prices, technical waste, as well as such 'out-of-spec' products should be taken along. Defining quality and costs like this, is something every mass producer should do. By applying these definitions, the actual efficiency of manufacturing systems becomes manifest. Inflexible processes can result into products having the wrong specifications. In products being waste. So much more flexibility is needed, to prevent that. Current innovations enable products to be economically customised today. By eliminating out-of-spec products this way, such Mass Customisation systems will actually be less costly in dynamic markets, than traditional mass producers.
Mass Customisation is the by end-users' demand activated mass manufacturing of individually customised products. Being capable of mass customising products, requires a dramatic increase in overall flexibility of mass producing companies, active in these dynamic markets.

Services are tailored to meet the needs of individual customers. The customer is often even actually involved in the production process. The identical characteristic that demand activated customised products (DAMA products) have. The one that differentiates the manufacturers of these customised goods, chiefly, from their mass producing colleagues. This ability to involve the end-user is precisely the characteristic that makes physical DAMA products 'service-like'. Mass Customisation is not just mass producing products to segments sized *one*. To manufacture DAMA products properly, both mass producing competencies, as well as service competencies will be needed. To understand this mix of competencies better, a metaphor, the customising pizzeria, was very helpful. It has resulted into a number of findings, with regard to (the quality of) the Mass Customisation of products.
DAMA organisations have to differ from traditional mass producing organisations, in order to be capable of mass producing such 'service-like', customised products. To move away from Mass Production, some structural innovations are needed at the production organisation, discussed in this report. A move that will take place almost defacto, if the proper definitions of quality and costs are applied.

After having explicated these characteristics and processes, it would be recommendable to check these in practice. To this, an actual demand activated manufacturer, Tulip in s'-Hertogenbosch, has been visited. Because of resemblance's between Tulip and Philips, the attained insights in visiting Tulip were expected

to be very useful, and valuable for comparing these to Philips. And indeed, the comparison shows a remarkable resemblance between the findings of the report, and those of Tulip. Also, I found that the discussed process characteristics of mass customisers, are actually, and clearly, present at Tulip. Therefore, the attained insights appear to be reasonably correct. Although, further testing would have been recommendable, yet impossible.
The findings are used in comparing them to flexibility improvement projects at Philips. To improve their logistic performances, Philips Sound & Vision has raised the FIL Supply Chain Management project. With the execution of this FIL project, a new value chain model will be constituted. FIL aims at ensuring satisfied customers, by bringing S&V to World Class Performance. In achieving the desired goal of becoming World Class in the dynamic markets of S&V in 2005, DAMA should definitely be present in the future FIL models. But it was not clear how the FIL changes proposed should accomplish this. Philips should incorporate DAMA, in order to really achieve World Class Performance.

A difficult bottleneck in becoming such a mass customiser, will be the capability of translating ranges of customer requirements into product design. This requires a platform design. And also the capability of producing the customised product within one or few days. Requiring product architectures to be 'DAMA-enabling'. For instance modularity permits the leveraging of a great number of product variations by mixing and matching different combinations of functional components. Economies of scale can still be obtained through the modules rather than the products. The modular components can be used over and over in different products. Without these capabilities, it is impossible to offer customised products timely, and less costly. Yet, only by applying the broadened definitions of costs, and quality, it will be clear that for instance modularity will result into lower overall costs. Tulip has confirmed that they consider this issue to be the most important enabler for Mass Customisation.

But having 'DAMA-enabling' architectures, will not guarantee customer desires to be fulfilled better. The risk of being out-of-spec, of producing waste, is still there. It is essential to have a real customer orientation also. Customer requirements should trigger short cyclic assembly processes, as well as long cyclic development processes. The quality in determining customer requirements properly, determines the product quality. The extent to what the product will actually satisfy the end-user. And for instance feedback of Lead-Users, is essential in managing the scope of platform designs properly. Without these long cyclic processes being penetrated by customers also, designs will probably provide the wrong scope of customisation.

Next important in starting the move to DAMA, is having responsive, slendered processes. Without, it is absolutely impossible to fulfil fast changing customer desires timely. Applying principles like Lean Thinking, Optimised Production Technology, Time-based Competition, Agile Manufacturing, Virtual Prototyping, and Virtual Manufacturing, is essential in being capable of coping with an increased competition, increased seasonality, fashion, and other demand variation. By taking more and more time out of the value chain, less and less (floating) stock will be needed. Also, customer requirements can reach the plant almost instantly, by electronically integrating the value chain.

If having platform designs, 'DAMA-enabling' architectures, a customer orientation, and slender processes, the techniques for attaining both economies of scale and scope simultaneously are needed. For instance Electronic Data Interchange, Computer Integrated Manufacturing, Computer Aided Design, Flexible Manufacturing Systems, etc. Yet, attaining these does not appear to be a severe bottleneck. They can be bought almost everywhere, pretty 'simple', if absent. Implementing these techniques could possibly bring up (severe?) cultural and organisational problems. Yet investigating this went beyond the scope of my assignment.

At Philips, practising the principle of Mass Customisation, could expose completely unexpected problems. Therefore, it's recommendable to start practising DAMA as fast as possible, in order to put Philips on the learning curve. But start implementing DAMA at the FIL entities, as discussed in the report, will probably take much time. In order to get onto the learning curve already now, Philips could start less complex DAMA projects. This could be done together with a partner. A service company, having those other competencies needed when mass customising products, besides the mass producing ones. Precisely for this, the Telepost services of the Dutch PTT have been discussed. A service turning electronic mail into physical mail. A real DAMA example, executed by a service company. The theories discussed in this report have been released to this PTT case, in accomplishing an actual, new DAMA proposal. This by extending these Telepost services currently offered by PTT Post. Executing this proposal in partnership with the Dutch PTT, can not only be very rewarding itself, yet could also be very valuable, and informative, in learning how to mass customise products in the future.

Table of contents

1 Introduction

1.1 Introduction

This report is a result of my graduate assignment of the Faculty of Technology Management at the Eindhoven University of Technology. Paragraph 1.2 describes the department of Philips where this assignment has been carried out. Radical changes in the market, to be discussed in paragraph 1.3, have given cause for the execution of this assignment. The increased power of customers, demanding more and more variety, forces companies to increase flexibility enormously, paragraph 1.4. Finally, paragraph 1.5 describes the structure of this report.

1.2 Company

Philips Electronics is a holding which consisted of nine Product Divisions. Philips Sound & Vision was such a Product Division, subdivided into several Business Groups. Business Groups like Audio, Video and Television. Now, these Product Divisions and Business Groups are transitioning into approximately 100 Business Units.
This graduation project has been carried out at the Business Development department of the Advanced Systems Applications (ASA) Lab, part of the Business Group Television. The Business Development department is not in particular engaged into the creation of really new business opportunities. Foremost, it's engaged into the establishing of new activities, and the improvement of existing ones, for the support of current businesses.

1.3 Changing markets

As we transition into the twenty-first century there are radical changes taking place that are reshaping the industrial landscape of western economies. The marketplace has become truly global. There's an increasing fragmentation of almost all markets. So companies like Philips have to cope with an increased competition, increased seasonality, fashion and other types of demand variation. Customers require more customised products, because they want to be treated individually. Delivering on short lead times and in quantities to suit customer needs, not manufacturing efficiency.

Companies like Philips gained its dominance through the system of Mass Production, further in this report abbreviated as MP. The frontier in business competition for most the twentieth century. Those companies are losing that dominance in large measure because MP could not handle the changes described above. Henry Ford got a huge organisation at River Rouge to take in iron ore and coal at one end and to turn out sheet metal on a fully assembled automobile at the other end in less than four days. But he limited his customers to one product; "You can have it any colour, as long as it's black".
Yet, radios, televisions, textiles, shoes, automobiles and a host of other goods have entered the mature stage of its life cycle. Its production processes are for purchase by all comers. Therefore, competition could increase dramatically. Really adding value will be done in those mass customising companies,

according to Maskell [h]. Only the companies able to distinguish, by producing exactly what the consumers really want, will survive in these highly dynamic markets.
And the call for variety can not simply be disregarded anymore, as Henry Ford did with the colour of his cars. He could, because he was the only, or one of few, mass producers of cars in the world at that time. Such a sellers market was characterised by high demand and a relative shortage of supply. In today's buyers' markets, companies can't afford NOT to listen to its consumers anymore. A company that does neglect the wishes of the final consumer, or even still neglects to listen at all, will lose the battle with its competitors. Because at least one of many competitors will listen.
So the increased competition in today's buyers' market has enlarged the assortment of alternatives for the consumers enormously. This has given the consumers an enormous power. A costly example of overlooking this power, where Philips was involved, has recently been given with the failure of Sport 7.

Figure 1.1: Cartoon showing the neglected power of the consumer by Sport 7. (Collignon [12]).

1.4 The need for delivering quality, for getting flexible

So, customer requirements get more and more varied. Moreover, this call for more variety can not be ignored. To understand the problem faced with properly, let's first (re-)define (overall) quality of products. Quality, of a product or a service, is more than conformance to product specifications. It also means meeting customer expectations. In (mass) production environments, often the product-based approach of quality is only used. This definition does not account for differences in customers wants and needs. It sees quality as a precise and measurable variable. Differences in quality reflect differences in the amount of some ingredient or attribute possessed by the product (Lovelock [40]). The traditional MP systems act technology push. Their products will not satisfy all potential customers, nor will they satisfy all customers to the same extent in today's buyers' markets.

A classic example is the remark made by a former Ford employee about his product: "This is a fantastic truck, there simply must be a market for it!" The Ford Transcontinental was indeed a first class vehicle, but it was too heavy and too expensive for the European market. So production had to be stopped (Mastenbroek [44]). So, despite being technically a highly qualitative product, this Ford didn't fulfil the desires of their European customers. Such worthless products should be called qualitatively poor! Therefore, quality should also imply the extent to what a product satisfies a customer, exactly the kind of product or service each consumer wants, in the right amount, at the right time, and for the right price. This is what Lovelock [40] calls the user-based definition of quality. It recognises that quality is only partly objective, yet also a subjective thing. Even for a mass produced good, the quality will be perceived differently by each customer.
The aspect of time is deliberately also incorporated in this definition of quality, although not common to do so. Yet, time is as important in satisfying customers, as the amount of some ingredient, or features of the product. After all, what good is the deliverance of an extremely tasty ice-cream or hot pizza, if the client is only able to eat it after an hour. Or a taxi arriving, for bringing you to the airport, if your plane has already left. (Overall) Quality, could therefore be considered as, 'simply' meeting the customers' requirements, according to Oakland [48].
Moreover, in overall quality, Rommel [56] draws a distinction between design and process quality. He defines design quality as: "a company's ability to develop products that meet the demands of the customer as closely as possible and to manufacture these products with the lowest possible defect rates." And process quality as: "a company's ability to manufacture and deliver a product to the specifications agreed with the customer." Both these definitions contain elements of the product-based, and the user-based approach of quality.

From these definitions, it can be derived that the call for variety, for better fulfilment of customer requirements, can be considered as being a call to deliver better quality. In this report the capability of delivering quality will be defined as being flexible! Then, overall flexibility is the company's capability to deliver design quality, and process quality, both product-based as well as user-based. The capability of meeting fast changing, individual customer requirements. And, all should be achieved at a cost that does not push the price too high in proportion to the by the customer perceived value of the product.

This definition of overall flexibility covers the flexibility of the current company and its systems. The flexibility, gained by incorporating a certain bandwidth into the systems. Chosen to be capable of delivering an expected, by the consumers desired, scope of products and features. Now, and in the (not to far away) future. Yet, it also covers the extent to what the company is able to react to opportunities, falling outside this fixed bandwidth. The flexibility in changing these systems, partial or entirely, if needed.

But, quality depends on what the competition is offering. When Henry Ford was offering his black Ford's, nobody was complaining. The alternative was buying a horse and a wagon. But this 'wagon' was driving all by itself! Therefore, the perceived quality was very high, obviously. Although, black was the only colour. But, imagine walking into a car dealership. You step into a new car, and guess what, there's no heating, the chairs can not be adjusted, no safety belts, the only colour is black, etc. You would be astonished, and asking where the hidden camera stands. Finally, after realising it is no joke, you will sneer to this dealer that its products are real trash. But, this car could, technically, be the best there is! Nevertheless the perceived quality will be lower than low. Why? Because it doesn't contain (standard) features, incorporated by all competitors. As products get more mature, more and more features have to be accounted for, in order to attain the same level of perceived quality. Now, for instance, an airbag has already turned into a common property! Yet, Henry had no need for adding colours. The fulfilment would not have been much higher, by adding colours, features. Only in a mature market it will. Relatively new products distinguish enough already, by its new technologies, or concepts.

Concluding, customer requirements become tougher and tougher in today's mature buyer's markets. In order to still be able to distinguish from competitors, it will even be necessary to manufacture products to the specific needs of each individual customer. This demand for high quality, highly customised products, asks for a dramatic increase in overall flexibility of mass producing companies, active in dynamic markets. More flexibility is needed, and this need can not be ignored, depicted in figure 1.1. So, the question to be answered in this report is HOW can Philips, partly such a production company, obtain this flexibility asked for in these dynamic, mature markets.

> As for the impact of robotics and other technologies on the factory floor, they've been overstated. Companies invested heavily in such technologies only to realise that they'd gone too far. In terms of flexibility, nothing is as flexible as a person. (Thomas [o]).

Yet, according to Warnick [66] and Thomas above, traditional views of flexibility have centred to much on manufacturing, the process itself and the machinery used. Important though this may be, full flexibility only comes with changes in culture, attitudes and organisational structure. From product concept to goods dispatch, every policy and procedure, system and process must have the objective of improving the flexibility and responsiveness of the whole company.

> **General Motors** spent in the early 1980s $40 billion for automation and new facilities to counter-attack the competitive pressure from Japanese automakers. They believed that if it spent enough on computers and robots, increased efficiency would be assured. But, with such a huge fixed cost, GM had to build a large volume of the same car model to break even. The rigidly designed production lines turned out more cars than GM could sell. As customers placed more emphasis on car features instead of cost alone, GM's huge investment proved to be a disaster. What GM learned is that simply organising work more efficiently and giving workers more say can produce more impressive results than millions of dollars worth of robots. (Warnick / Lau [66 /38]).

Mikio Kitano, Toyota's director of production engineering, has also long been a proponent of automation during his career. Yet, in 1990, Kitano argued for paring automation in Toyota plants. It wasn't paying for itself to a sufficient degree. He believed, that it was because robots were being used in too many places. Human beings could do the job just as well, and for less cost. (Miller [45]). Obviously, nothing is as flexible as a person!

> Unfortunately, most productivity improvements are concentrated at the shop floor level. And in spite of substantial gains in this area, a number of Western countries lose the battle due to rising overhead cost. Improvement in the managerial and social infrastructure and the bureaucratic superstructure is bound to be very rewarding. (Dr. P.P. Naraayanan, President of the International Corporation of Free Trade Unions, at a symposium in Seoul, South Korea).

Therefore, the flexibility of the production plant is NOT the main topic of this report. Flexibility must be present in all significant activities; recognition of the situation, determination of strategy, product development, production (assembly) and marketing. Only limited rationalisations and improvements in efficiency and flexibility can be obtained if production, assembly is considered in isolation.

In highly dynamic markets, the entire production company has to move away from MP systems like Ford's, to new, more flexible ways of organising production. Systems enabling the use of flexible technologies that do exist. Enabling the creation of new, more responsive processes and management methods. Exploiting flexibility to more quickly develop and produce new products and services that (more) closely match individual tastes. These extremely flexible systems, capable of even mass customising products, form the main topic of this report. It will be discussed and explained that those systems can outperform Mass Production systems in dynamic markets. The underlying principles, enablers of those systems will be discussed also. It will be shown how many companies are successful, by obtaining flexibility through implementing the different principles to be discussed. The report will indicate which course should be taken by Philips in becoming such a flexible mass customiser. The most essential steps, in attaining the capability of surviving in these highly dynamic markets, will be denounced. Also, an actual mass customisation proposal will be given.

1.5 Structure report

Summarising, in order to gain money, customers should be satisfied properly. But customer requirements become tougher and tougher in today's mature buyer's markets. In order to still be able to distinguish from competitors, companies should be capable of producing high quality, highly customised products. Being capable of mass customising products, requires a dramatic increase in overall flexibility of mass producing companies, active in these dynamic markets. This has been depicted in the upper part of figure 1.2, showing the structure of this report.

To make this essential move to Mass Customisation, further abbreviated as MC, the first step should be the achievement of faster, more responsive processes. These slendered processes will be better capable of coping with an increased competition, increased seasonality, fashion and other types of demand variation. Without first achieving such fundamental improvements, any flexible technology tools will only give minimal benefits. Four principles, for achieving these fundamental improvements, will be discussed in chapter 2. Lean Thinking, Optimised Production Technology, Time-based Competition, and Agile Manufacturing.

Survival increasingly depends on the ability to adapt to fast-changing conditions. Big bureaucrats and clumsy mainframes can't do that. To become a really flexible organisation, the discussed process improvements should be implemented into completely new organisational forms. The virtual company, to be discussed in chapter 3, could well be this organisational model of the years ahead. It consists of a temporary network of independent business partners: customers, suppliers, even former rivals. This leads to a flexible, and very dynamic corporate structure. Chapter 3 will also discuss how virtuality can make the office, and the design process faster, more flexible. Essential in fulfilling customer desires better.

The agile, virtual organisations, are so fast and responsive, enabling to make the next move. The fulfilment of the exact desires of each individual customer! They are capable of incorporating the principle of MC. The Mass Production of individually customised goods and services, to be discussed in chapter 4. Mass customisers produce exactly the product asked for, becoming demand activated this way. These highly flexible systems enable consumers to activate their power, discussed above. This in contrast with Mass Production systems.

In order to really become a demand activated mass customiser, it will also be necessary to look at products differently as used to. In Demand Activated Manufacturing Architectures (DAMA), the customer deals directly with a salesperson, in determining its exact desires. This interaction with a potential client is completely new to mass producers of physical goods. Producing what the customer desires, is something what these manufacturers are not, but service organisations are familiar with. Therefore, chapter 5 will look at physical goods as if it were actually intangible services. In order to help understand how to customise physical products properly, a pizzeria metaphor will be used.

After having explicated these characteristics and processes of mass customising products, it would be recommendable to check these in practice. To this, a real DAMA example, will be discussed in chapter 6. It will indicate the practical value of the findings of chapter 5. After having looked at this real mass customiser, a fairly good image of the flexible organisation should have been obtained by then. An image that will be compared to the current value chain improvement project of Philips, FIL. Also, the theories discussed in this report will be released to a PTT case. This to actually accomplish a new DAMA proposal. Finally, in chapter 7, the resulting conclusions and recommendations will be given. As mentioned, the discussed structure of the report has been depicted in figure 1.2 below.

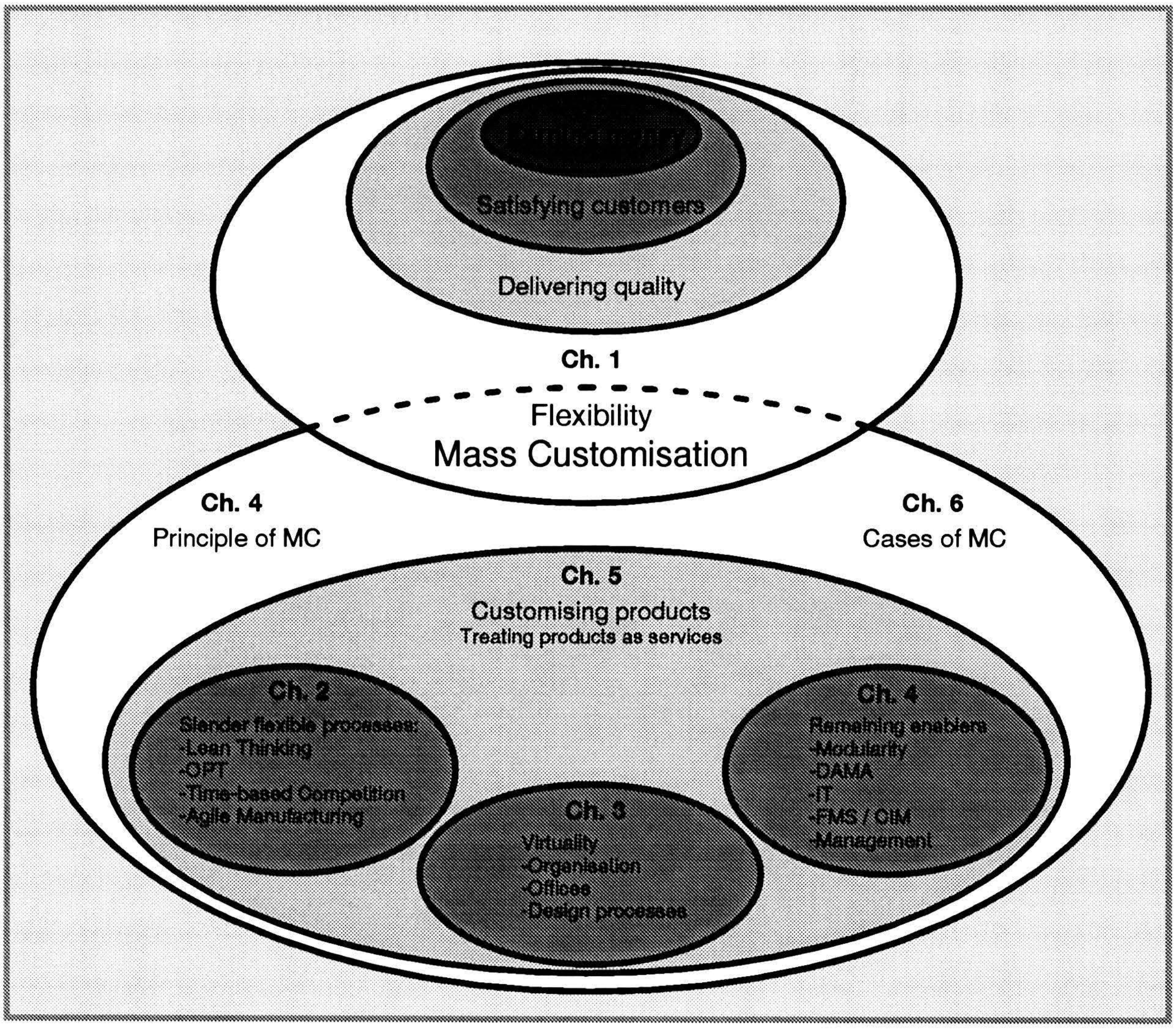


Figure 1.2: Structure of report.

At the introduction of each paragraph, the structure of figure 1.2 will be showed again, to indicate once more the place of the concerning chapters in this report.

Many examples of companies, are given in lightly shaded boxes in this report, as shown below. These are facts, and have been accomplished already! Thus, it should be recognised when reading, that these companies could even be much further now!

> Example of a lightly shaded box, black letters.

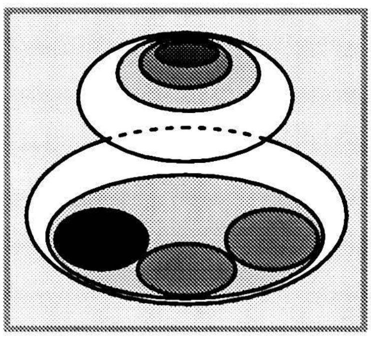
Statements, made by concerning specialists, are given in dark shaded boxes, see below. These statements are not always in accordance with the beliefs of the author, as will then appear from the concerning comments made.

Example of a dark shaded box, white letters.

In this report, several cartoons are also depicted. These, mainly *American*, cartoons show that the problems mentioned are definitely not specific to Philips. They form part of many Western companies, manufacturing or selling mass products.

2 Flexibility by increasing organisational responsiveness & effectiveness

2.1 Introduction



As discussed in chapter 1, the entire production organisation has to move away from MP, to new, more flexible ways of organising production. The first step should be the achievement of faster, simplified, and responsive processes. Those slender processes will be better capable of coping with an increased competition, increased seasonality, fashion and other types of demand variation. Without first achieving such fundamental improvements, any flexible technology tools will only give minimal benefits. Four principles, for achieving these fundamental improvements, will be discussed in this chapter. They have all in common the aim for increasing speed, increasing flexibility as discussed in paragraph 1.3.

At first paragraph 2.2 will deal with the principle of Lean Thinking. Lean Thinking provides a way to specify value, and to line up value-creating actions in the best sequence. To conduct these activities without interruption whenever someone requests them, and perform them more and more effectively. Resulting in less human effort, less equipment, less time, and less space, while coming closer to providing customers with exactly what they want.

Optimised Production Technology (OPT) is a philosophy and software product to be discussed in paragraph 2.3. It focuses around the constraints (bottlenecks) or weak points of the system which fundamentally affect the whole process. OPT identifies these key constraints to the achievement of business objectives, and exploits these constraints to optimise overall company performance.

Greatly reducing time throughout a firm's value chain has become known as Time-based Competition, to be described in paragraph 2.4. Time-based competitors are offering greater varieties of products and services, in less time and at lower costs than their slower competitors. As will be seen, companies are obtaining remarkable results by focusing their organisation on responsiveness.

Lean manufacturers and time-based competitors are very good at doing the things they can control. Agile manufacturers deal with the things they can NOT control. Agility is the ability to do well in an environment of constant and unpredictable change. Agile manufacturers achieve their rapidity by co-operation with their former rivals. This principle will be discussed in paragraph 2.5. Finally, paragraph 2.6 will give a summarisation.

2.2 World Class Manufacturing and Lean Thinking

World-Class means being the best in your field in the world. According to Todd [63], best can be in terms of:

- Quality and reliability.
- Least manufacturing cost.
- The ability to keep introducing innovative designs more quickly than your competitors.
- Shorter lead times and more reliable delivery performance.
- Customer service performance.

Mass producers in the USA and Europe led the world in industrial efficiency. In those days, Japanese productivity levels lagged behind. Generally, their products had a poor reputation for quality. That started to change in the 1950s. A number of Japanese companies, led by Toyota, decided to bring their performance up to the standards set by the Western world. Production experts such as Shigeo Shingo in Japan and quality gurus Juran and Deming from the USA, developed new ways of improving manufacturing performance. It enabled them to make a step change in both quality and productivity.

This change enabled them to even overtake their competitors in the West. They became widely recognised as the most efficient volume car manufacturer in the world. And they continued to draw ahead of the rest of the world thanks to faster rate of their ongoing continuous improvement activities. World Class Manufacturing or Lean Manufacturing is therefore also often called the Toyota Production System (TPS).

2.2.1 Lean Thinking

The principle techniques of World-Class Manufacturing are:
- Total Quality Management (TQM).
- Just-in-Time (JIT).
- Lean Manufacturing.
- Teamwork (total employee involvement).
- Continuous improvement.

There is considerable overlap between these different approaches. They are all placing particular emphasis on eliminating waste, called muda in Japan. Waste is any human activity which absorbs resources but creates no value. Some examples are:
- Mistakes which require rectification.
- Production of items no one wants so that inventories and remaindered goods pile up.
- Processing steps which aren't actually needed.
- Movement of employees and transport of goods from one place to another without any purpose.
- People in downstream activities, waiting because upstream activities have not delivered on time.
- Goods and services which don't meet the needs of the customer.
- Time spent in changing set-ups between batches.

According to Womack [35], there is a powerful antidote to muda: Lean Thinking. A way to specify value, and to line up value-creating actions in the best sequence. To conduct these activities without interruption whenever someone requests them, and perform them more and more effectively. Lean Thinking is lean because it provides a way to do more with less and less. Less human effort, less equipment, less time, and less space, yet coming closer to providing customers with exactly what they want.

Womack [35]described the five principles of Lean Thinking. The critical starting point is value. Lean Thinking must start with defining value in terms of specific products with specific capabilities offered at specific prices through a dialogue with specific customers. This by ignoring existing technologies and assets, and to rethink firms on a product-line basis with strong, dedicated product teams. This requires redefining the role for a firm's technical experts and rethinking just where in the world to create value.

Creating value has traditionally been described as a model called the value chain. It is a series of value-adding activities that connect a company's supply-side with its demand-side, see figure 2.1. Identifying the entire value chain for each product (-family) is the next step in Lean Thinking. A step which firms have rarely attempted but which almost always exposes enormous amounts of muda, according to Womack [35].

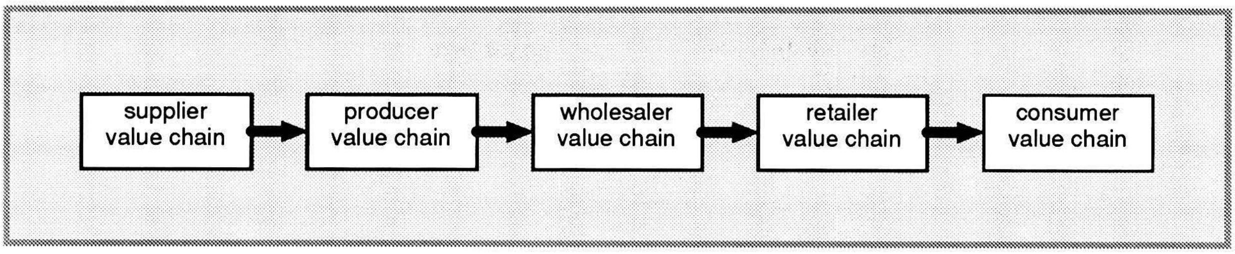


Figure 2.1: The value chain.

Once value has been precisely specified, the value chain for a specific product is fully mapped, and obviously wasteful steps are eliminated, it's time for the next step in Lean Thinking. Make the remaining, value-creating steps flow, without interruptions. Tasks can almost always be accomplished much more efficiently and accurately when the product is worked on continuously, from raw material to finished good. Things work better when you focus on the product and its needs, rather than the organisation or the equipment. This needs the conversion from departments and batches to product teams and flow.
The first visible effect is that the time required to go from concept to launch, sale to delivery, and raw material to the customer falls dramatically. When flow is introduced, products requiring years to develop are developed in months. Orders taking days to process are completed in hours. And the weeks or months of throughput time for conventional physical production are reduced to minutes or days. This way shifting demand can be accommodated immediately. The real revolution is the ability to design, schedule, and make exactly what the customer wants, when the customer wants it. This demand activated manufacturing will be discussed in chapter 4.

The four initial principles, discussed above, interact with each other in a virtuous circle. This process is the fifth and final principle of Lean Thinking, perfection. Getting value to flow faster always exposes hidden waste in the value chain. And the harder you pull, the more the obstacles for a continuous flow become visible, so that they can be removed. Almost the same as with the river of inventory of JIT. There, the lower the water level, the more the inventory obstacles become visible.

2.3 Optimised Production Technology

Optimised Production Technology (OPT) is a philosophy, and software product, that aims at starting a process of ongoing improvement into a business. It is focused around the constraints (bottlenecks) or weak points of the system which fundamentally affect the whole process. The OPT techniques are also discussed in the literature under the terminology of Constraint Management or Theory of Constraints.

Traditionally, OPT seeks to balance the flow of materials through a plant by finding the constraints present in the manufacturing process. But OPT has evolved from a scheduling tool into a methodology, capable of coping with all kinds of logistic problems. OPT can be used for the whole supply chain, where even greater benefits can be gained.

OPT identifies the key constraints to the achievement of business objectives, and exploits these constraints to optimise overall company performance. Then it focuses management actions onto those areas that will provide the best return for improvement effort. OPT accurately models the critical variables in business, such as demand, product mix, capacity, manpower, material availability and logistics. This way, OPT can help achieve the best balance of customer service, expense and throughput. OPT can be employed as a detailed shop floor scheduler, a high level planning simulator or a supply chain manager.

There are some fundamental rules, traditionally driving businesses (Fox [18]):
■ Balance capacity, then try to maintain flow.
■ Level of utilisation of any worker is determined by its own potential.
■ Utilisation and activation of workers are the same.
■ An hour lost at a constraint is just an hour lost at that resource.
■ Constraints temporarily limit throughput but have little impact on inventories.
■ Splitting and overlapping of batches should be discouraged.
■ Schedules should be determined sequentially:
Predetermining the batch size;
Calculating lead time;
Assigning priorities, setting schedules according to lead time;
Adjusting the schedules according to apparent capacity constraints by repeating the above three steps.
■ The process batch should be constant both in time and along its route.

Conventional Motto: The only way to reach a global optimum is by insuring local optimums.

Contrarily, in the OPT approach (Fox [18]):
■ Balance flow not capacity.
■ The level of utilisation of a non-constraint is not determined by its own potential but by some other constraint in the system.
■ Utilisation and activation of a resource are not synonymous.
■ An hour lost at a constraint is an hour lost for the total system.
■ An hour saved at a non-constraint is just a mirage.
■ Constraints govern both throughput and inventories.
■ The transfer batch may not, and many times should not, be equal to the process batch.
■ Schedules should be established by looking at all of the constraints simultaneously. Lead times are the result of a schedule and cannot be predetermined.
■ The process batch should be variable not fixed.

OPT Motto: The sum of the local optimums is not equal to the global optimum.

The essential message of the OPT philosophy, as can be deduced from the statements above, is that management efforts should be focused on the constraints (bottlenecks) and its predecessors. These are the critical activities. Every hour saved in this part of the value chain, will increase responsiveness by one hour. Yet, focusing on non-critical activities and its successors will only give minor advances.
By removing a bottleneck, the bottleneck will shift to another part of the value chain. By focusing again on this new bottleneck, a process of continuous improvement is started. An excellent way of speeding up a value chain, specified by the Lean Thinking method of the preceding paragraph.

Columbus Stainless in Johannesburg produces 150.000 tonnes of stainless and chromium steels a year. After implementing OPT software, they were able to reduce WIP (work in progress) inventory by 60%. Raw materials inventory went down from 50.000 to 10.000 tonnes, and lead times could be reduced from 60 days to 20. ([n]).

The OPT approach to manufacturing is unique and is used by many thousands of companies. OPT applied manually, can already result into substantial benefits. However for really dramatic improvement, the power and speed of software is the only real solution [n].

2.4 Time-based Competition

Greatly reducing time throughout a firm's value chain has become known as Time-based Competition. Time-based competitors are changing their measures of performance from competitive costs and quality to competitive costs, quality, and responsiveness. According to Hout & Stalk [30], each point along the flow must drastically alter itself, reducing cycle times and increasing variety, to provide whatever customers want when they want it. To this, the discussed Lean Thinking method, and OPT philosophy, can be of great help in taking time out of the value chain.

Citicorp introduced Mortgage Power in 1987. It promised the buyer and the realtor a loan commitment in *fifteen days* or less. The typical loan originator required 30 to 60 days to make a commitment. Demand for Citicorp's mortgage loans was growing more than 100 percent per year in an industry with an average growth of 3 percent per year. In the second year of the program, Citicorp was the largest mortgage loan originator in the U.S. Management was looking to triple its share in less than five years. On February 8, 1989, Citicorp announced that henceforth mortgage commitments would be made in *fifteen minutes*. (Hout & Stalk [30]).

Time-based competitors are offering greater varieties of products and services, in less time and at lower costs than their slower competitors. Companies are obtaining remarkable results by focusing their organisation on responsiveness. Each of the U.S. companies discussed here, uses its response advantage to grow at least three times faster in the U.S. than other companies in the industry and with profitability's that are more than twice the U.S. industry average [30].

Wal-Mart is one of the fastest growing retailers in the United States. Its stores move nearly $20 billion of merchandise a year. Only K-Mart and the floundering giant, Sears are larger. Wal-Mart's success is due to many factors not the least of which is responsiveness. Wal-Mart replenishes the stock in its stores on average *twice a week*. Many stores receive deliveries daily. Their competitors replenish their stock every two weeks. Compared to these competitors, Wal-Mart can:

- maintain the same service levels with one-fourth the inventory investment.
- offer its customers four times the choice of stock for the same investment in inventory.
- do some of both. (Hout & Stalk [30]).

What we all better focus on is selling customers what they want to buy; not what we manufacture, not what we want to promote, not what we bought on forward buys, but selling customers what they want to buy, when they want to buy it, as efficiently as possible. My view of the distribution system in the '90's and where it's headed is that every body becomes a partner together. We simplify it to the point where there's no mystery, no suspicion, no guessing games and everyone knows exactly how it works. (The Wal-Mart CEO David Glass [f]).

All agree that Quick Response (QR) cannot be done alone. QR requires the involved parties to establish partnerships. By working closely together to better understand each other's businesses and needs, QR creates faster turn-arounds and lower inventory levels.

Atlas Door can reliably respond in three to four weeks because it has structured its order entry, engineering factories, and logistics, to move information and product quickly and reliably.

Atlas Door is now the leading supplier of industrial overhead doors in the United States. These doors involve considerable variety, with many possible choices of width, height dimensions and material. Most doors must therefore be manufactured to order. Atlas can fill an order for an out-of-stock door in three to four weeks, one third the industry average. Customers are rewarding Atlas Door's responsiveness by buying most of their doors from them, often at 20 percent price premiums. Atlas Door is growing *three* times faster than the industry, and it is *five* times more profitable than the average firm in the industry. (Hout & Stalk [30]).

First, Atlas built just-in-time factories. Extra tooling and machinery substantially reduces changeover times. The fabrication process is organised by product. It schedules so that most all of the parts needed to fulfil an order for a door can be started and completed at about the same time.
Second, Atlas automated its entire order entry, engineering, pricing, and scheduling processes. Today 80 percent of all incoming orders can be priced and scheduled while the caller is still on the phone. Special orders can be engineered quickly because the amount of re-engineering has been substantially reduced. This by preserving the design and production data of all previous special orders.
Third, Atlas developed a system to track the parts in production and the purchased parts for each order. This to ensure that all parts arrive at the shipping dock in time and at the customer site at the same time.
Applying the principles of Time-based Competition, Atlas Door was able to increase its flexibility enormously. And as a result, its price realisation was not only high, but its streamlined and effective processes were even lower cost!

In the late '80s, **Whirlpool Corporation's** inability to meet service requirements of long-standing customers like dealers and contractors began to undermine business. In 1989, David Whitwam purchased N.V. Philips' floundering European appliance business. This catapulted Whirlpool into the number one position in the world-wide appliance industry. His vision was to supply any customer, any day, with as little as a single unit of product within 24 hours. A tall order considering that more than 3 million units of 950 different models are produced annually in Whirlpool's five major U.S. plants and are inventoried in hundreds of dealer warehouses.
Yet, using a network of strategically located, integrated regional logistics centres and its 'Quality Express' transportation fleet, Whirlpool slashed order cycle time from *14 days* to *24 hours*, significantly reduced costs, and took large quantities of inventory out of the supply chain. Furthermore, improved service levels have delighted customers, raising Whirlpool's service rating to first in its industry. (Gunneson [24]).

The time advantage is enabling time-based competitors to upset traditional leaders of their industries. A time-based competitor with turnaround times three to four times faster than its competitors, will almost always grow three times faster than the average for all competitors. Moreover, these estimates are floors, according to Hout & Stalk [30]. Many time-based competitors grow faster and earn even higher profits relative to their competitors. The example of a former Philips unit above, suggests that Philips, in principle, should also be able to accomplish such results itself.

2.4.1 Time-based Competition in the apparel industry

The apparel industry in the United States is moving to provide QR to customers through the multi-company value chain of retailers, apparel manufacturers, textile mills, and fibre producers. In 1985, The Crafted with Pride, proposed tying all the various operations together. Their vision is to have "the right product at the right place at the right time at the right price". Before, new styles took from fifty-six to

sixty-six weeks to reach retail customers. Led by The Limited and Levi Strauss at the retail and apparel manufacturing levels, and Milliken and Du Pont at the textile and fibre manufacturing levels, firms throughout the industry are re-engineering their processes. By all linking together, the entire chain knows what is selling at the retail level, and therefore what to produce and distribute at each preceding level in the chain. (Pine [52]).
Major progress has already been accomplished in the replenishment cycle: reordering, producing, distributing, and restocking of existing styles. The industry has reduced the time from twenty-five weeks towards six weeks in 1993, with a stated "ideal" of two weeks. At six weeks, and especially at two, retailers can order much smaller amounts of many more styles, then reorder what customers really want most.

According to Pine [52], the following tactics have proven useful to a variety of organisations in implementing a strategy of providing Quick Response throughout the value chain:

- Companies can start by simply working faster, and with fewer people.
- In redesigning processes from scratch, use available tools and techniques (redesign, not reinvent).
- Provide those closest to the customers, with all information and authority necessary to make decisions.
- Eliminate the succession of approvals, up and down the layers of management, slowing organisations.
- Create within and outside the organisation, partnerships for fulfilling requirements of end-users.
- Measure time: development cycle time, production cycle time, distribution cycle time, percentage of time spent in value-added activities, customer response time, percentage of sales from products and services less than a year old, etc.

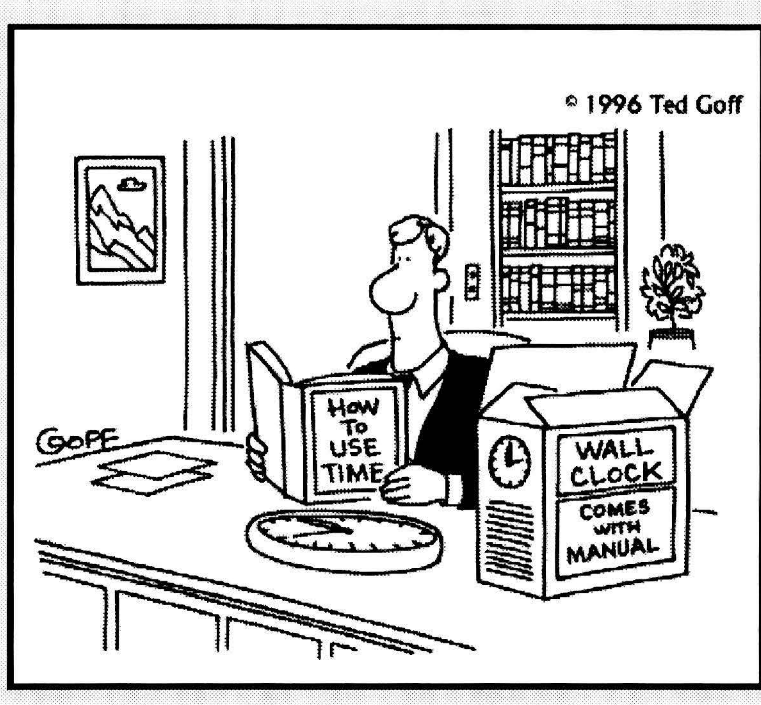


Figure 2.2: Using time properly, can be a very complex, yet rewarding issue! [c].

Fast replenishment at Benetton leads to better fulfilment of customers' desires. Retailers need to stock fewer items of each type, thus can stock more variety in the same shelf space. Beyond the replenishment cycle, gains are also being made in the cycle from design to initial delivery. The competitive advantage of providing new designs that satisfy customers' wants and needs is far greater than that of replenishing existing stock. Increasing variety becomes easier, more effective, and even cheaper than in the old ways of MP. Fast development, manufacturing, and distribution cycles allow companies like Benetton and The Limited to refresh their styles constantly to match their consumers' wants at any given time. (Pine [52]).

> Since October 1993, Italian producer **Benetton** has linked his retail shops, its sales agents, its supplier network, and its ultra-modern unmanned production plants. Through short-cycle, networked production techniques, computer-driven laser cutting, full-automatic sewing, and through the ability to dye products after their manufacture, it's able to international customise its products. Benetton is consistently able to replenish stock in any country, centrally from Italy, in less than *one week.* (Geursen [20]).

The faster and faster replenishment of apparel will decrease the amount of items to be stocked more and more. Also decreasing the amount of lost opportunities of additional sales, because of selling out. Yet, only by producing what the customer really wants, by letting this customer activate manufacturing, will eliminate these amounts completely. Optimising the fulfilment of the customers' desires. This is the principle of MC. With the exception of mass-customised T-shirts, few companies are able to do this today. Two companies that can are Custom Cut Technologies, and Custom Vêtement Associates.

> Retailers tied into **Custom Cut Technologies'** systems can use proprietary potentiometer technology to measure each individual. The measurements are sent electronically to the operation in Cleveland. There, CAD software pulls up the pattern from a database and dynamically changes it to fit the individual. A laser system cuts the pattern, and a traditional sewing shop produces the final garment. Elapsed time: *three weeks,* in 1991. And, at that time, aiming for reducing it to *7 to 10 days.* (Goldhar & Schlie [23]).

> **Custom Vêtement Associates**, the U.S. subsidiary of French apparel manufacturer Vestra, has taken further time from the manufacturing process. Every night the data are sent to a central computer in New York and beamed via satellite to France. In the morning, after nine inspectors look at different pieces of data, a computer-controlled laser cutter selects the appropriate material and cuts the garment. A staff of tailors does the finishing touches, the suit is shipped within *four days.* (Pine [52]).

According to Pine [52], providing QR throughout the value chain is a great way to begin the shift to MC. Time-based Competition focuses an organisation on meeting needs of customers as quickly as possible. This allows more variety to be produced at lower costs. It can begin anywhere in the value chain, pulling or pushing the rest of the chain along with it.

> **The Peerless Saw Company** developed a computer-driven laser system for cutting saws. Together with other process improvements, this led to delivery time dropping from *fourteen weeks to three.* After this, customers began experimenting with the design of the blades because Peerless could get them developed and manufactured so quickly. The company took advantage of this by next dramatically reducing the order cycle. It gave the sales people portable terminals tied into its main system. This way they could sit down with customers and together design a new saw. Once that was completed, the manufacturing process was initiated directly from the customer's shop. (Pine [52]).

The principles of MC, and examples of other practitioners of MC outside the apparel industry, will be discussed in chapter 4 elaborately. The Peerless Saw Company provides a good example of time-based strategy starting in manufacturing and development, spreading to its marketing and distribution processes. The end result, mass customised saws.

2.5 Agile Manufacturing

As depicted in front of this report, In the TV series Star Trek [39], actors are often shown requesting things from the ship's computer, to have them manufactured and available immediately. The ability to move along the manufacturing process at such pace, is the real-world goal of Agile Manufacturing (Port [54]).
Agile Manufacturing research is being executed by the National Science Foundation and the Pentagon's Advanced Research Project's Agency. In November 1991, the Iacocca Institute at Lehigh University also began a national initiative to create Agile Manufacturing enterprises. Their goal is to link customers, suppliers, and manufacturers into a kind of super efficient confederation, increasing manufacturing pace.

Where MP achieved low unit costs by producing large quantities of uniform products, the new system achieves agility. Capable of producing far smaller quantities of high quality, highly customised products at low unit costs. In an agile enterprise, what a factory produces today will be driven by yesterday's retail sales, or an order received moments ago from an on-line partner. Manufacturing machinery can be reprogrammed quickly to produce new products, in many variations.
Lean or World Class Manufacturing is very good at doing the things you can control. Agile Manufacturing deals with the things we can NOT control. Agility is the ability to do well in an environment of constant and unpredictable change. With MP, even with the enhancements of Just-in-Time and Lean Manufacturing, corporations attempted to do everything themselves. Competition favoured large scale, comprehensive, operations. The Agile Manufacturing system favours smaller scale, modular production facilities, and co-operation between enterprises.

Some of the principles of Agile Manufacturing [54]:
- Everything is changing very fast and unpredictable.
- The market requires low volume, high quality, custom & specific products.
- Products have very short life-cycles, very short development and production lead times are required.
- MP is outdated. Customers want to be treated individually.
- Perfect quality and very high levels of service are expected and required.
- Products and services become information-rich.

An agile approach to manufacturing faces the reality that customers must be served with small quantities of custom designed parts with perfect quality, 100% on-time delivery, and at very low cost. To approach Agile Manufacturing requires that the company already be World Class and using Lean Manufacturing methods. This is a starting point. You can only build agility on a firm foundation. (Maskell [h]).
The need for agility is most apparent in highly dynamic, mature markets, see also chapter 1. New products are coming very fast there. According to Maskell, only the innovative and agile companies will survive the changes in those mature markets.

At **Mack Trucks Inc.**, customers used to wait *14 months* for some trucks. But Mack now can fill many of the orders in *60 days*. The trucks are customised work tools, and Mack is working on agility in making them. (Viola [64]).

In Australia, the supermarkets for instance, have been adding 500 sku's (stock-keeping units) every year with very few elimination's. Every product comes in an enormous variety of sizes, packs, and variations (diet, low sodium, decaffeinated, kids size, etc.). These trends lead away from the old ideas of large factories making huge quantities of relatively few standard products. Already the pharmaceutical industry, the metals industries, garments industries, supplies, and many others are seeing the start of this customisation trends. According to Maskell [h], other industries will follow in only a few years.

> Representatives of **The Goodyear Tire & Rubber Corporation** say agile techniques helped the company do a major turnaround. It chopped management layers from *35* to *7* and now has at least one plant capable of making *215 products*. (Gunneson [24]).

> The Lordstown engine dress line of **General Motors Corporation** began incorporating agility early in 1992. The incorporation was completed in 1993 with these results: line flow improved enough to free up 27 percent of the former floor space for other activities. Inventories dropped 48 percent, and lead times were reduced by 38 percent. Productivity increased 39 percent. (Gunneson [24]).

The agile enterprises are really fast, and responsive. They are flexible manufacturing enterprises, capable of even manufacturing customised products, activated by the demand of an individual end-user. These demand activated manufacturers, mass customisers, will be discussed thoroughly in chapter 4.

> You do what you're good at, keeping your core competencies in-house and then outsource whatever you need to. A key aspect of agility is co-operation. That's the way it's going in the future and it's opened a lot of doors for us. Now, instead of having 400 competitors, we have 400 potential customers. (Ed Kinsella, sales and marketing manager for JM Mold, a manufacturer of die case and plastic injection molds [36]).

One of the most powerful competitive weapons of Agile Manufacturing will be, according to Pine [xx], the ability to form virtual companies routinely. In the USA, the Iacocca Institute at Lehigh University proposed a national industrial network, the Factory America Net (FAN). FAN build a comprehensive industrial database with services, allowed to be accessed by groups of companies. Its operation assumes the removal of legal barriers to multi-enterprise collaborations. And the creation of standard consortium formation models that make forming a virtual company as straightforward as making a will or forming a corporation.

In the vision of FAN, companies should be able to search the network for the right knowledge, skills, experiences, and technologies they need to apply to a project. To create and sign agreements with selected partners, and file the necessary documents for the creation of a virtual enterprise. And finally, exchange all of the information for the running of that enterprise, including market opportunity documents, engineering drawings, prototype specifications, manufacturing or service process standards, customer databases, etc. Personal meetings and telephone or videoconferencing will of course still be desirable if not necessary for the effective running of a virtual enterprise. But the network will provide the primary mechanism for integrating its value chain. These virtual enterprises, and its virtuality tools, will be discussed in the next chapter.

2.6 Summary

In becoming a flexible organisation, it is very important to get insight in how value is created along the value chain. In applying the principle of Lean Thinking, it will then be possible to make a value chain as effective as possible, by eliminating all human activity which absorbs resources but creates no value.
A philosophy that can be of great help in setting priorities for determining on what waste to focus, is the OPT philosophy. Its essential message is that management efforts should be focused on the constraints and its predecessors, the critical activities. Because every hour saved in this part of the value chain, will increase responsiveness by one hour. Focusing on non-critical activities, will only give minor advances.
Lean Thinking, OPT enable companies to take time out of the firm's value chain. This has become known as Time-based Competition. Time-based competitors are capable of offering greater varieties of products and services, in less time and at lower costs than their slower competitors. It allows them to exploit their slendered, flexible processes, so that they can fulfil customer desires much better than their rivals.
Quick Response is a great way to begin the shift to Mass Customisation. This capability, of manufacturing, and delivering customers exactly the desired product, is the real-world goal of Agile Manufacturing. Mass Customisation will be discussed extensively in chapter 4.

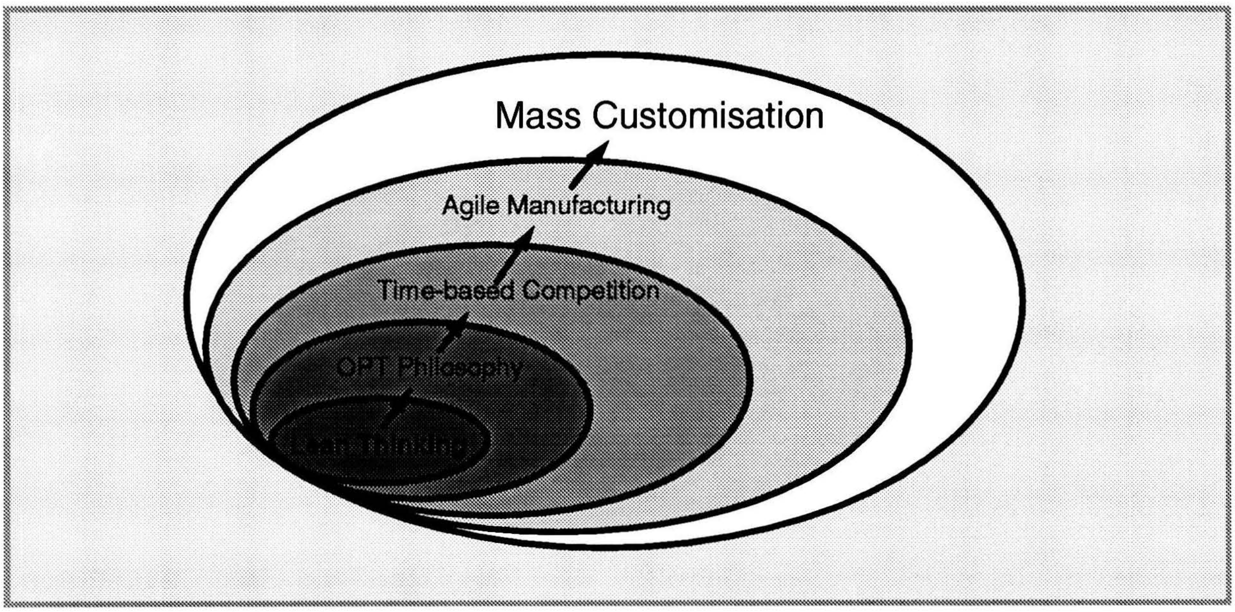
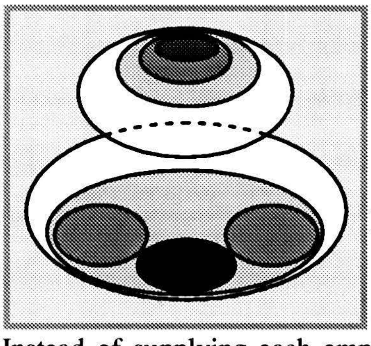


Figure 2.3: Structure of chapter 2.

Once more, figure 2.3 above, depicts that each paragraph, principle discussed in this chapter, provides a step forwards to the principle of MC. But as mentioned in chapter 1, attaining slender flexible processes for speeding the value chain, reflects only one of many aspects in becoming a mass customiser. The next chapter will discuss another aspect in obtaining a flexible, mass customising company, namely virtuality.

3 Flexibility by virtuality

3.1 Introduction



As discussed in chapter 1, survival increasingly depends on the ability to adapt to fast-changing conditions. Big bureaucrats and clumsy mainframes cannot do that. They are the wrong models for the 1990s and beyond. To become a really flexible organisation, the discussed process improvements of chapter 2, should best be implemented into completely new organisational forms. The virtual company, to be discussed in paragraph 3.2, could well be this organisational model of the years ahead. A temporary network of independent business partners: customers, suppliers, even former rivals. Leading to a flexible, very dynamic corporate structure.
Instead of supplying each employee with an office and a desk, many (virtual) companies will find it cheaper and more flexible to equip workers with computers, faxes, and communications gear and allow them to make their own working arrangements. These flexible virtual offices will be discussed in paragraph 3.3.
Obviously, in order to become flexible in all partitions of the organisation, the design process will have to change dramatically also. Increasing attention has to be given to speed up part development, taking into account all the considerations related to the product directly at the early design stage. Great advances gained in networking technology, groupware graphical user interfaces, multimedia, and the decrease of computing costs, enable such new Rapid Prototyping, and Virtual Manufacturing approaches. Approaches, reducing cycle times and costs in product development. This, by performing design tasks in parallel, using virtuality tools. On the other hand, today's dynamic, turbulent markets, together with the call for more variety, even customisation, 'demand' an enormous speed and effort of the design department. All put together, this imposes the exploitation of these approaches. These approaches, will be discussed in paragraph 3.4. Finally, paragraph 3.5 will give a summarisation.

3.2 The virtual organisation

In a business world of fast-moving global markets and fierce competition, the windows of opportunity are often small. Then, according to Chorafas & Steinman [10], survival increasingly depends on the ability to adapt to the fast-changing conditions. Entrepreneurs who act aggressively and are right in the majority of cases, but not in all. Something the large centralised corporation is ill-prepared to do. Today's clumsy corporate tyrannosaurs struggle and fail, as the stories of IBM, GM, Sears, Philips, and so many others tell. Such big bureaucrats and clumsy mainframes are the wrong models for the 1990s and beyond [10].

It is better to have 80 percent right decisions if you make them fast and implement them agressively, than think you can be 95 percent right and take a year in delays (Percey Barnevik, chief executive officer of Asea Brown Boveri [h]).

The concept of corporate downsizing of the past decade, and its implementation, failed to break the vertical chains of command typical in most giant companies. Massive layoffs of middle managers have led to fewer layers of management. However, essentially the same hierarchical organisational structures were left. Really new organisational forms are needed [10].

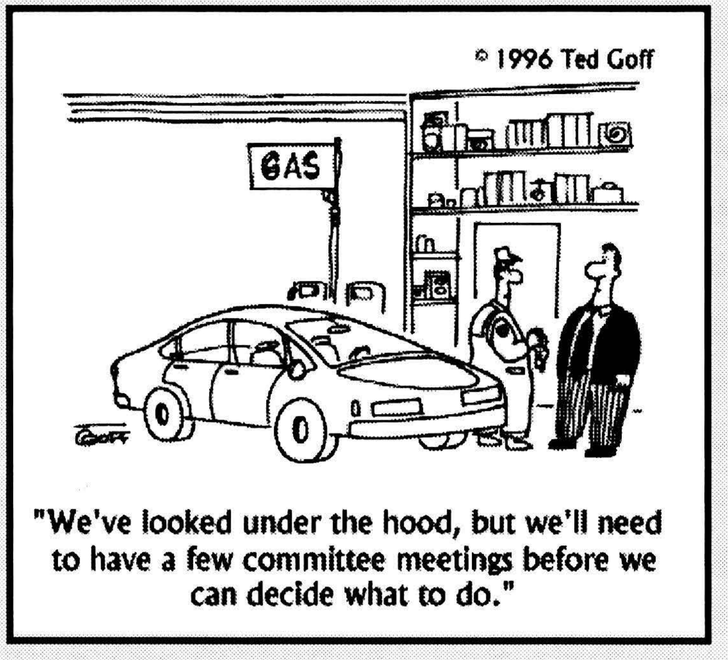


Figure 3.1: Vertical chains of command. [c].

According to Chorafas & Steinman [10], the virtual company could well be the organisational model of the years ahead. It consists of a temporary network of independent partners: customers, suppliers, even former rivals. These are linked by information technologies, enabling them to share R&D expertise, manufacturing capacity, management skills, markets, and costs. This leads to a flexible, very dynamic corporate structure.

Geursen [20] defined the virtual company as: “a company not physical present at a building, yet only existing in the minds and the computers of these companies, as an indication of a (temporarily) collaboration of people”. Johanson [33] as: “the ability to create a partnership across companies throughout the entire supply chain. Companies band together synergistically so that they can dominate the market”.

No company can have all the required skills and knowledge. In high-tech areas very often strong, small organisations develop and harness the latest advances. There may be additional services, information, or logistics required to meet the need, according to Maskell [h]. To achieve these diverse and ever changing needs requires great co-operation. This co-operation is needed within the firm. Often traditional companies have very little flexibility and co-operation from one department to another. This must be solved and the various departments or areas of the company must work together for the enrichment of the customers, irrespective of the department's short term benefit.
In some cases the company will need to create a virtual corporation from several parties to focus on meeting the needs of a customer. Virtual corporations are opportunistic alliances of core competencies

across several firms. This to provide focused services and products to meet the customers' needs. The best manufacturer will manufacture the product, the company with the most advanced R&D will design it and they might hire the best marketing company in the country (or world) to market the product [h].

> You must understand your customers use of your products more thoroughly than they know themselves. To address the customers' real needs you must sell solutions and not products. Selling solutions requires a detailed and thorough understanding of the customers' needs, and requires bringing together a package of products and services to fulfil those needs. Your product alone may not be enough. You may need to add extra services or technical support or special terms. You may need to add complementary products supplied by other companies, perhaps by your competitors, to truly satisfy the customers needs. (Maskell [h]).

The virtual company has no permanent hierarchy which spreads ten layers down the line. It has no vertical integration in terms of raw materials, semi-manufactured goods, and finished products. This way a new fluid and flexible corporate model is created. The solution is based on a group of collaborators who quickly unite to exploit a specific opportunity and then disband once that opportunity has been seized.

> **IBM, Motorola, and Apple Corporation** have linked to develop the new PowerPC chip to compete with the Intel Pentium. The companies, in some aspects competitors with each other, have created a team to design, develop, and manufacture the PowerPC chip. None of them could have done this alone. (Maskell [h]).

Usually there is no complex legal structure. Co-operative arrangements are quickly made, and then put into practice. Virtual corporations require trust, respect, and openness. New technologies, Internet, video conferencing, and multi-lingual systems provide the level of personal contact required to work together effectively, and in a timely manner. They allow groups of people to work together effectively, even if geographically separated. Enabling the creation of virtual corporations. (Maskell [h]).
According to Maskell [h], the local people in those organisations must have complete authority, within the vision and principles of the company, to address the customers' needs. For local decision-making to be effective, a company must have highly educated employees. People who know and understand the company's vision and principles. People who know and understand the customers' requirements. And people who know and understand the company's products and services.

Paragraph 4.5.1 will revert to these virtual organisations. It will be discussed that a firm's decisions about the kinds of product designs it creates may largely determine the organisation structure it must adopt to develop, produce, and service those products. According to Sanchez [xx], applying modular product architectures, enables the formation of these virtual organisations.

3.3 The virtual office

Instead of supplying each employee with an office and a desk, many (virtual) companies will find it cheaper and more flexible to equip workers with computers, faxes, and communications gear and allow them to make their own working arrangements. When these employees need to work at the company office they will use non-territorial or virtual offices or videoconference facilities. This significantly reduces time lost in commuting to the company's office, and produces less stress and fatigue.

In 1993, **Intel** France began instituting the virtual office with their marketing people. Intel salespersons now work out of home offices. An Intel salesperson spends only *4 hours* per week in the company office, rather than 40. The rest of the time, he or she is with clients or works out of a home office. (Chorafas & Steinman [10]).

In the United States, a number of companies, including Digital Equipment, IBM, Anderson Consulting, and Ernst & Young, have already introduced virtual-office solutions. General Electric aims at reducing its office space in America 40 to 50 percent. It calls its program the office of now, rather than the office of the future!

In Europe, **IBM** is in the process of squeezing the staff from 18 buildings in and around Paris into 6. Some 5000 'nomad' workers will now work away from the corporate base. Already some work groups have been able to give up *70 percent* of the space they occupied. In rent alone, IBM is saving $105 million annually. (Chorafas & Steinman [10]).

Management needs to have the right feeling for these new ventures before starting. Putting managers from an old culture in charge of a new one rarely works. Business and industry have to recognise and accept the fact that entrepreneurs cannot thrive in rusty and crumbling structures. Neither can innovations be run in the same way as the old. You can not, like Exxon late 70s early 80s (and Philips?!), put old senior managers, near retirement and deeply embedded in the company's control attitude, in charge of new entrepreneurial cells, whose business is completely foreign to them. (Chorafas & Steinman [10]).

Once the old managers are given carte blanche to kill a project, the entrepreneurs will quickly leave to do their innovative job somewhere else, and the new venture will sour. A major innovation can't succeed with a bunch of old boys who know nothing about virtual offices, virtual companies, or virtual reality, and who do not see what they stand for in the first place. (Chorafas & Steinman [10]).

3.4 The flexible design process

Organisations have to become flexible in all partitions to become really flexible. Decisions made during the design stage can have significant effects on product cost, quality and lead time. So increasing attention has to be given to speed up part development, taking into account all the considerations related to the product directly at the early design stage. Therefore, the design process will have to change dramatically also.
Great advances gained in networking technology, groupware graphical user interfaces, multimedia, and the decrease of computing costs, enable new development approaches. Paragraph 3.4.1 will deal with Rapid Prototyping (RP), or Virtual Product Development (VPD). A new approach to reduce cycle times in product development. This by employing virtual as well as physical prototyping technologies.
Virtual Manufacturing (VM), is the use of a desk-top virtual reality system for the Computer-Aided Design of components and processes for manufacture. It allows a much earlier manufacturing involvement in the product development, by providing the capability to 'manufacture in the computer'. VM will be discussed in paragraph 3.4.2.

Today's dynamic, turbulent markets, together with the call for more variety, even customisation, 'demand' an enormous speed and effort of the design department. This imposes the exploitation of these approaches. Approaches, creating a responsive and flexible product creation process. Particularly interesting, since this graduate assignment has been carried out at the Philips ASA (TV) Lab.

3.4.1 Rapid Prototyping with virtual reality tools

As already stated, Rapid Prototyping (RP), or Virtual Product Development (VPD) is a new approach to reduce cycle times in product development. The key issue of RP is the tight organisational and informational integration of the development team. This, in order to shorten development iteration cycles, despite spatial separation. To decrease development costs, by employing virtual as well as physical prototyping technologies.

> **Benetton Formula Ltd.**, winner of the Formula One World Driver's Championship in 1994, has invested substantially in developing an effective, and efficient IT infrastructure. Multimedia tools allow effective collaboration among engineers working at diverse locations. Benetton's technical center in Oxford, a wind tunnel in Farnborough, a permanent test facility at Silverstone, and race and test circuits worldwide. The limitations of information exchange by phone and fax have been brought into focus by an ever-increasing need for rapid design and modification work. ([e]).

> **Nippon Electric** (NEC) has designed a prototype that can bring up to five people together in a simulated environment. In this manner, engineers in different laboratories can work on a common design problem over a network, and benefit from the features offered by 3D real time graphics. The environment NEC has designed can be both immersive and non-immersive. In the former, users wear gloves and 3D glasses to interact with each other over the network. (Chorafas & Steinman [10]).

So far, RP with virtual reality has been very limited, because computers and software haven't been powerful enough. Yet, great advances gained in networking technology, groupware graphical user interfaces, multimedia, and the decrease of computing cost enable the advanced use of RP tools today. The tools give the possibility to create a virtual environment in which all the experts involved can perform all the necessary analysis in parallel, even among geographically dispersed groups.

> In its Mannheim factory, the German factory of **Asea Brown Boveri** has a virtual reality project in parallel in two of its plants in two different locations. This very effectively permits concurrent engineering for design, and plant engineering for operational reasons. (Chorafas & Steinman [10]).

Similarly as with the discussed virtual enterprises that span the world with their customers and suppliers, designing (prototyping) becomes a truly distributed activity. In the highest stage of RP, all aspects of the product creation process are performed collaboratively and concurrently across departments, sites, divisions, alliances, suppliers, and geography's. Moving product development into the marketspace allows the participation of managerial and design talent from around the world in the development process. It eliminates the limitations of time and space that characterise development processes in the physical world, creating the ability to share data 24 hours a day! Technologies like *video conferencing* enable immediately returning suggestions of part modifications that can be simultaneously evaluated by the different members of the team and then accepted, refused or negotiated. This intensified co-operation of development teams by means of advanced information technologies, combined with the utilisation of fast prototype manufacturing technologies, is how the rapidity of RP is achieved.

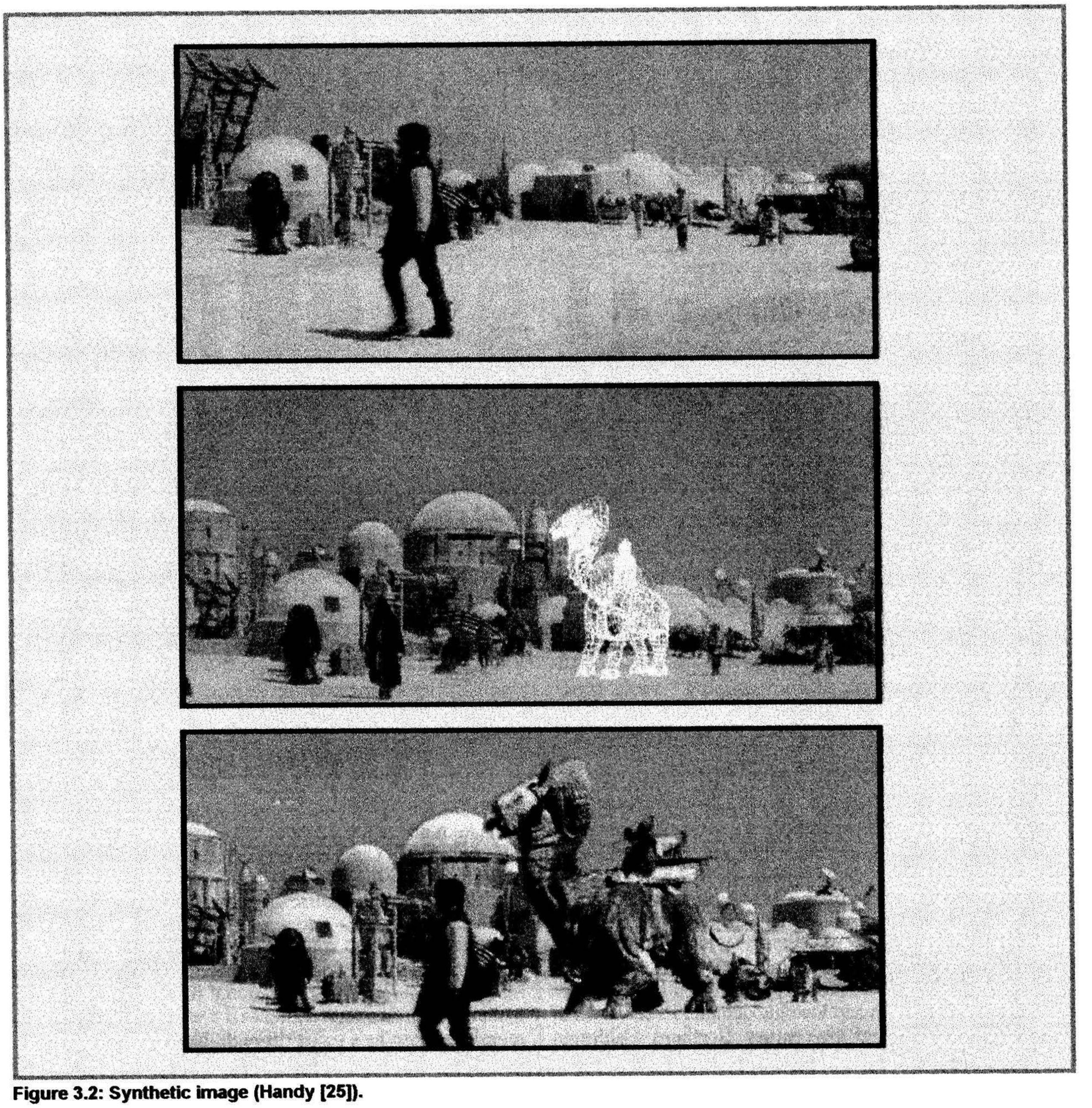


Figure 3.2: Synthetic image (Handy [25]).

Virtual Prototyping software enables an engineering team to build a virtual model of anything with moving parts, and then simulate full-motion behaviour. The design can be optimised long before building the first physical prototype. With today's emphasis on Total Quality Management, component-level optimisation as traditionally with Computer-Aided Design (CAD), isn't enough. Today, engineers demand the ability to view their designs at the system level, showing the interrelated effects of motion on the complete product.

We have to take virtual testing tools and integrate them into every part of the business. I see . . . three shifts of people working eight hours a day on that equipment, to really make us faster to the market. We think it is only limited to your imagination. (John Ivanko, CAD/CAM manager for General Motors Corporation's North American Operations manufacturing prototype shops [m]).

Virtual Prototyping lets you look at the system in a visual way, with a strong analytical foundation, so you think at the system level, not the component level. As a manufacturer, you're not interested in selling a box of components. You're selling a complete product that must function as a system, a highly integrated system. (Dr. David Cole, Director of the Office for the Study of Automotive Transportation, University of Michigan [j]).

Haug & Kuhl [27] defined virtual prototypes as: "computer based simulations of a prototype system or subsystem with a degree of functional realism that is comparable to that of physical prototypes".

The fact that today the degree of realism of virtual prototypes can be compared with that of physical ones, is induced by the tremendous advances in modelling and simulation technologies. Figure 3.2, left page, gives an indication of the degree of realism and sophistication available currently. Above, a frame from the original Star Wars movie is depicted. But the current advances mentioned, enabled this movie to be embellished considerably. Middle, shows a trial run with a model for a new digital creature a 'Ronto'. Bottom, the special, renewed version. The 'Ronto' and some other creatures have been added, and the background is built up. The movie shows that synthetic images are not distinguishable anymore from actual physical persons, models, or film-sets. The by scanning and copying qualitatively affected picture, gives only some indication of that, unfortunately.

The advantages of developing virtual prototypes and the integration of these in the product creation process:

■ Reduction of time: Time-to-Market is a key marketing issue related to competitors. It may be lost sales due to delayed product releases. The added labour costs resulting from multiple "build-and-break" cycles using physical prototypes. Whatever, time delays in development can result into tremendous added costs.

Bharat Earth Movers Ltd. (BEML) is the third largest heavy equipment manufacturer in the world. They perform all motion behavior of their earth movers with physical prototypes. Testing systems on physical prototypes used to require *a full year* of effort. Now, with the help of virtual prototyping, BEML's engineers perform the same tests in less than *a quarter of the time*. ([k]).

Hendrickson is one of the top builders of truck suspensions. Their products are used by Kenworth, Ford, Mercedes-Benz, and other major truck manufacturers. In the past, Hendrickson engineers relied heavily on physical prototyping to analyse their suspension designs. This was a very time-consuming and expensive process. Now, they use virtual prototyping to help keep the time and cost of design and testing down. By making simple "what-if" changes to these virtual prototypes, they can *instantly* test the effects of alternative suspension designs. This also gives them an effective visual means of explaining new design concepts to their OEM customers. ([k]).

In today's extremely fast markets, companies don't even have the time to build and test multiple physical prototypes, as in the past. Virtual prototyping allows testing new designs in just a couple of days, giving the freedom to try things companies never had the time or money to do with physical prototypes.

- Saving cost: virtual prototypes will reduce the number of physical prototypes, reducing development time, but also the manpower, as well as the tools and material. Also, early prototyping results can feedback to the design stage timely, before production costs are already fixed. The example below shows how virtual reality technology indeed lowers costs. And because digital assets are not used up in their consumption, companies creating value with them, can reuse them through a potentially infinite number of times.

> **Fokker Space & Systems** is one of the few companies in the Netherlands engaged in the development of virtual reality applications. In Ede, they built a special building, called 'dome' or 'cave', for the Dutch army. A many millions costing simulator for the practising of firing the *one million guilders* costing Stinger ground-to-air missiles. (Wiegerinck [67]).

> **Mitsubishi Corporation** of Japan has standardised on the use of virtual prototyping for everything from electrical switches and circuit breakers to passenger cars and satellites. Engineers use parametric models created with virtual prototyping software to automatically validate the designs of their complete line of circuit breakers. They've eliminated all but the final hardware prototype from the design cycle, and have cut 6% from overall development costs. This translates into *billions of yen* saved. ([k]).

According to Dr. Orr, technology consultant and futurist, the cost of correcting a product design flaw increases exponentially as a manufacturer gets deeper and deeper into the development cycle. Therefore, an engineering team really has only one good choice, and that is to make its design mistakes early, preferably before building physical prototypes [j]. If there is a failure during traditional testing of physical prototypes, the cause of failure is often not obvious. One result is that engineers will over-design components since they are unsure that all operational conditions will be adequately tested. Virtual Prototyping will eliminate this need for over-designing, saving time and costs.

> The cheapest and least traumatic place to crash your plane, to sink your ship, to drop your cargo, to jam your mechanism, is on the computer, with virtual prototyping. (Orr [j]).

- Increase of quality: the evaluation of different alternatives of the design can be realised in the virtual environment much faster and cheaper. This allows for a better evaluation of the appropriate solution to serve the given requirements best, because of more (virtual) prototypes. Improving quality will also decrease, or perhaps even eliminate, costly, and harmful recalls.

Audi has distributed tapes of virtual prototyping simulations to its dealer network. Audi salespeople can use these tapes in the showroom to vividly demonstrate how the vehicles respond to varying driving conditions. Including hazards such as panic stops, icy roads, and sudden high-speed lane changes. It's a persuasive way to communicate the unique advantages of Audi's products. ([k]).

Audi shows how the achieved increase in quality by using Virtual Prototyping can be effectively demonstrated to their potential clients by using the same prototyping tools!

N.V. Nederlandse Spoorwegen (Netherlands Railways Ltd.) can quickly and easily build complete railcar models with the proper constraints, forces, and loads on components. Their engineers can then animate their models and display graphs of important parameters on their computer screens. Virtual prototyping significantly improves the quality and efficiency of railcar engineering by making it easy to test and refine their designs many times before building hardware prototypes. In the past, the time and expense of physical prototyping made multiple design iterations impractical. Now they can explore *hundreds* or even *thousands* of design variations in wheel sets, suspensions, etc. ([k]).

But, is the information you collect from Virtual Prototyping as reliable as the results you get with physical prototypes in the test lab, in test flights, or on the test track? This is often the chief concern of engineers and managers when they first consider the use of Virtual Prototyping. After all, what good is saving time and cutting costs if test results fail to reflect the mechanism's actual performance in real-world conditions? According to the users of Virtual Prototyping tools at Ford Motor Company, these simulations are highly accurate. In validating results, they haven't needed to change anything. Their simulations have been *entirely* consistent with actual vehicle performance. ([j]). Pellerin Milnor Corporation, an industrial laundry equipment manufacturer, uses Virtual Prototyping in developing washer, extractor machines. This to reduce the transmission of motion to the floor. Test results on the physical prototype matched the virtual model at a level of about 95%. ([i]).

Annex 1 describes the use of Virtual Prototyping by Caterpillar, the world-wide manufacturer of tractors, loaders, and other off-highway equipment. Annex 2 describes how Imax Corporation, known from their theatres, projecting films onto a screen up to *eight stories* high, uses Virtual Prototyping to help design and test the film-transport mechanism for a new 210mm camera. Tolerances are very tight, with accuracy's of *ten millionths of an inch* in certain areas!

3.4.2 Virtual Manufacturing

Virtual Manufacturing (VM) is the use of a desk-top virtual reality system for the Computer-Aided Design of components and processes for manufacture. It allows a much earlier manufacturing involvement in the product (process) development, by providing the capability to 'manufacture in the computer'. Creating and viewing three-dimensional engineering models, later to be passed to Numerically-Controlled machines for real manufacturing. Ultimately, VM will provide a modelling and simulation environment so powerful that the fabrication (assembly) of any product, including the associated manufacturing processes, can be simulated in the computer.

On July 1994, the VM User Workshop was held in Dayton, where three paradigms emerged [p]:

- Design-Centred VM: adds manufacturing information to the product creation process with the intent of allowing simulation of many manufacturing alternatives and the creation of many 'soft' prototypes by 'manufacturing in the computer.'

- Production-Centred VM: adds simulation capability to manufacturing process models with the purpose of allowing inexpensive, fast evaluation of many processing alternatives.

> **Freudenberg**, a $3.3 billion privately owned company, has the policy of emulating a real-life business environment in its plants in Kaiserslautern, Germany. Management steadily seeks to improve upon past solutions. Recently, for example, for the simulation of its textile plants prior to final design, it introduced an audio facility able to emulate real-life factory noise, and ensure that legal noise levels are observed. (Chorafas & Steinman [10]).

- Control-Centred VM: is the addition of simulation to control models and actual processes, allowing for seamless simulation for optimisation during the actual production cycle.

In summary, Design-Centred VM provides manufacturing information to the designer during the design phase. Production-Centred VM uses simulation during production planning to optimise lines and / or factories, including the evaluation of processing alternatives. Control-Centred VM uses machine control models in simulations, the goal of which is process optimisation during actual production.

VM will, according to the participants of the VM User Workshop [p], contribute to realising the following benefits:

- Affordability: reliable cost and process capability information that can impact management decisions, and key design, and support system performance with manufacturing cost, schedule and risk. Because, as already mentioned, digital assets are cheap, and not used up in their consumption.
- Quality: more producible designs moving to the shop floor and higher quality work instructions to support production.
- Producibility: first article production that is trouble-free, high quality, involves no reworks, and meets requirements. Optimise the design of the manufacturing system in co-ordination with the product design.
- Flexibility: the ability to execute product changeovers rapidly, to mix production of different products, and to return to producing previously shelved products.
- Shorter cycle times: increased effectiveness of the product creation process and the ability to go directly into production without false starts.
- Responsiveness: the ability to respond to customer 'what-ifs' about the impact of various funding profiles and delivery schedule with improved accuracy (credibility) and timeliness.
- Customer relations: improved relations through the increased participation of the customer in the product creation process, lower costs, better schedule performance, improved quality, and greater responsiveness.

Annex 3 describes a case of RP, and VM, at Benetton Formula Ltd. The need for effective communication is accentuated here by the exceptional time constraints under which the racing engineers have to operate. Grand Prix races are only two weeks apart, and they have realised that every hour counts if they want to be able to use most of their time to carry out modifications and improvements. With their people often spread over several different sites or in transit between race track and factory, they need to implement the most collaborative communication technology available.

3.5 Summary

As depicted in figure 1.2, the slender flexible processes provide the capability of becoming an Agile Manufacturer. Manufacturers capable of mass customising products. These companies are able to exploit business opportunities very fast. But large centralised organisations are ill-prepared to do so. Thus, the discussed process improvements of chapter 2, should best be implemented into completely new, flexible organisational forms. Such virtual companies, can adapt to fast-changing conditions.
Within these virtual organisations, virtuality can be of great help in making these organisations even faster. Instead of supplying each employee with an office and a desk, workers will be equipped with computers, faxes, videoconferencing facilities, etc. They will work at home, or at the company using non-territorial or virtual offices.
Virtuality can also be applied in creating a responsive and flexible product creation process. Rapid Prototyping, or Virtual Product Development, and Virtual Manufacturing approaches, reduce cycle times and costs, and increase quality in product development, using virtuality tools.
As in chapter 2, a figure, depicts the coherence of the paragraphs of this chapter, as discussed above.

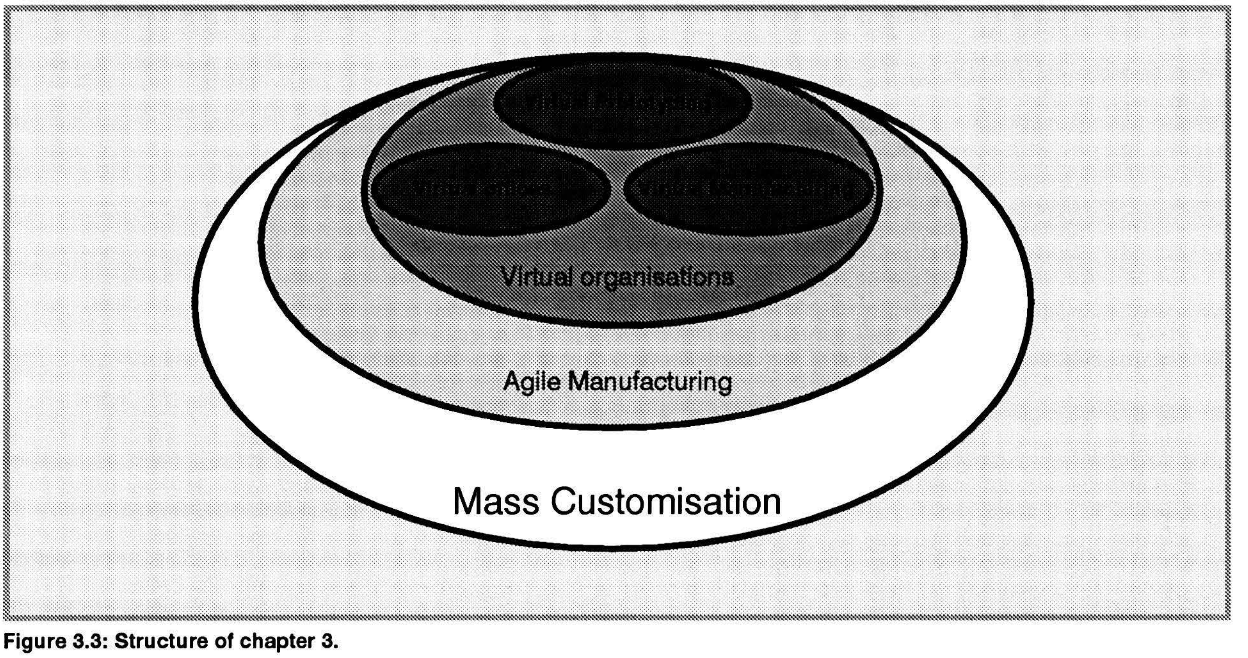
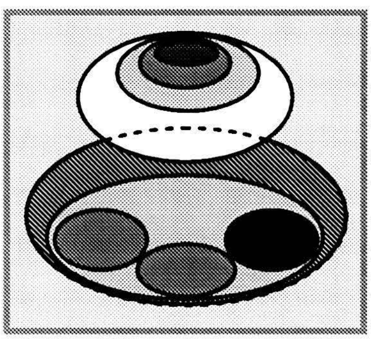


Figure 3.3: Structure of chapter 3.

Thus virtuality can help agile manufacturers in mass customising products. At last, the next chapter will discuss this principle of Mass Customisation, referred to already so many times. Chapter 4 will also discuss the other enablers of MC depicted already in figure 1.2, besides the ones already discussed extensively in chapter 2, and 3.

4 Flexibility by mass customising products and services

4.1 Introduction



According to Pine [xx], becoming a quick and responsive organisation is a great way to begin the shift to Mass Customisation (MC). The synthesis of the two long-competing systems of management, Mass Production (MP), and Craft Production. Thus it's the mass production of individually customised goods and services. In contrast with MP, these systems enable the consumers to activate their today's power, because the production organisation becomes demand activated. The principle of MC will be introduced in paragraph 4.2

MC will, overall, be cheaper in dynamic markets, according to the discussion in paragraph 4.2. But, in very steady markets, MP can still be more efficient. Markets where competition is small, and everything produced can be sold, like Philips with its light bulbs. So, the discussion demands an indicator, in comparing the efficiency of MP and MC systems. This, performance indicator will be introduced, and discussed in paragraph 4.3. There are different ways of customising products and services. Gilmore & Pine [21] have identified four distinct approaches, to be discussed in paragraph 4.4.

As promised, this chapter will deal with the remaining enablers, achieving both mass and customisation together. Without these innovations, *Mass* Customisation would not be, economical, possible. Paragraph 4.5 discusses: Modular product architectures, Demand Activated Manufacturing Architectures (DAMA), innovations in information technology, the Virtual Value Chain (VVC), Flexible Manufacturing Systems, and new ways of management. Paragraph 4.6 will discuss the issue that the product and process life cycles will become decoupled in MC. Concluding, a summarisation will be given, in paragraph 4.7.

4.2 The new paradigm

A way of incorporating variety, producing individual customised goods and services, could be simply going back to Craft Production. But where the variety and flexibility of Craft Production are required, its costs are to high. What's wanted is a production system with the low costs of MP, combined with the flexibility of Craft Production. A synthesis of these two long-competing systems of management, resulting into the Mass Production of individually customised goods and services. That's the principle of Mass Customisation (MC). At its core is a tremendous increase in variety and customisation without a corresponding increase in costs. This by creating variety and customisation through flexibility and Quick Responsiveness. It is the Mass Production of individually customised goods and services.

> Manufacturing is fast entering a new age of industrial excellence: Mass Customisation. Not only clothes, but a huge variety of goods, from autos to computers, will be manufactured to match each customer's taste, specifications, and budget. MC will mark the culmination and synthesis of Agile Manufacturing, virtual companies, and Total Quality Management. (Port [54]).

Mass customisers have thrown away the old paradigm of MP, whose focus was efficiency through stability and control. Their world is no longer stable, cannot be controlled, and therefore their operations cannot be kept efficient in the old way. Through the application of technology and new management methods, they have found their way to the new paradigm of MC.

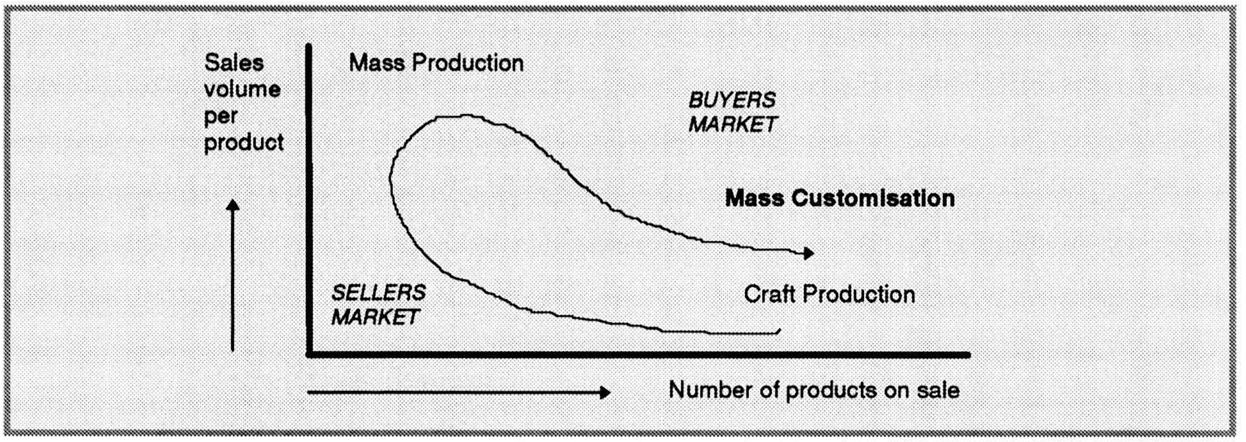


Figure 4.1: From Craft Production to Mass Customisation (Womack [35]).

In figure 4.1 above, Craft Production is succeeded by MP, in which a small set of products has to be made in large volumes. MC returns to Craft Production in the sense that a large set of products is made in small volumes, but now with the economy of scale of MP. The logic of MP is, that lower prices result in greater sales, greater sales in higher volumes, higher volumes in lower costs, and lower costs loop back around to allow even lower prices, etc. Here, low costs are achieved primarily through economies of scale.
Pine [52] described the new logic of MC. A company that better satisfies its customers' individual wants and needs will have greater sales, higher profits, and a better understanding of customer requirements. The company can provide even more variety and customisation, which further fragments the market. Because it is outdistancing its competitors in variety and customisation, market fragmentation allows it once again to better satisfy its customers' individual wants and needs, and so on.
So, in MC, low costs are achieved primarily through economies of scope. A single process can produce a greater variety of products or services more cheaply and more quickly. Mass customisers can often achieve both. Economies of scale on standard components or modules, that can be combined in a myriad of ways to create end-product variety with economies of scope. Referring to the definition of flexibility in paragraph 1.3, these mass customisers can be depicted as extremely flexible. Because of the capability of delivering both, design-quality, and process-quality, highly and simultaneously.

Motorola's 'Fusion' manufacturing system for pagers allows a customer, from 1993 already, to phone in an order for a customised pager. It provides automated translation of the customer's description into product specifications and bills of materials for the desired pager. Offering upwards of *29 million* different combinations of pager features. Then it schedules and manages production of the pager on a flexible assembly line. Within *17 minutes* of receipt production begins! Finally it ships the customised pager to the customer, within *24 hours*. (Johnson & Stroebel / Yovovich [34 / 68]).

While the practitioners of MP share the common goal of developing, producing, marketing, and delivering goods and services at prices low enough that nearly everyone can afford them, practitioners of MC share the goal of developing, producing, marketing, and delivering affordable goods and services with enough variety and customisation that nearly everyone finds exactly what they want. (Pine [52]).

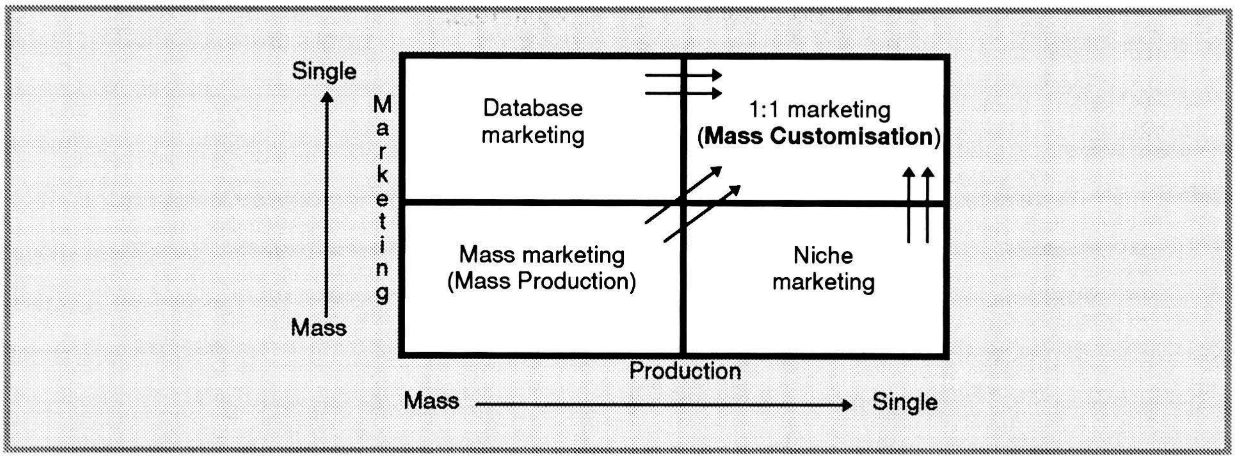


Figure 4.2: Customer differentiation matrix.

MC is fundamentally different from the product differentiation approach from mass producers. There clever marketeers try to differentiate products, in order to approach different groups of customers with different variants of products. In MC the customer is the point of departure, not the product. This one-to-one marketing approach of MC, addresses oneself to the individual customer, not to customers grouped by postcode or age. See figure 4.2 above. Because, as Goldhar & Schlie [23] stated: "It is not enough to be differentiated; one has to be differentiated in ways the customer values." The latter is guaranteed by the MC approach, for the products manufactured are actually demanded by the end-user! The manufacturing process is only activated *after* identifying the exact demand of that specific customer, see paragraph 4.5.2.

Yet, Goldhar & Schlie also stated that: "it is not enough to be differentiated in ways that the customer values. The differentiation has to be achieved at a cost that does not push the price so high that the value to the customer is perceived to be less than that of a less differentiated, lower-priced alternative."
"A firm that can achieve and sustain differentiation will be an above-average performer in its industry if its price premium exceeds the extra costs incurred in being unique. A differentiator, therefore, must always seek ways of differentiating that lead to a price premium greater than the cost of differentiating" (Porter [55]).

Mass-produced clothing will always be cheaper than clothing produced on an individual basis. (Johnson [g]).

It used to be axiomatic that achieving higher levels of quality meant higher costs. But we know now that building quality into processes lowers costs. The same is true of customisation. Building it into processes can indeed lower costs. Remember that in this report, flexibility was defined as the capability to deliver quality. It may be assumed to be a matter of common knowledge, in which ways incorporating quality lowers costs. So the capability of delivering quality, flexibility, is an ability to lower costs.

But, in what ways will incorporating flexibility, specifically by becoming a demand activated mass customiser, lower costs? In the foregoing paragraphs and chapters, many of the following explanations were already brought up. Here a summarisation:

- In Demand Activated Manufacturing Architectures, nothing is produced until the desires of the customer are actually known. Therefore, everything what's produced, will be sold. The customer is already known. There's no necessity of marking down unwanted, already produced products, as in MP.

With the risk of annoying the people who bought that same product recently for the full amount. That will effect their perceived quality of the product, possibly effecting potential re-buys.

- Because the customer tells you precisely what to manufacture, the desires of the customers can be fulfilled optimally. With MC, only and exactly what each customer requires will be done, eliminating wasted features for example. And, mass customisers gain competitive advantage by better satisfying customers' individual wants and needs, allowing them to ask even higher prices. Perhaps, the entire brand of such a company will prosper by their boosted esteem, by customising only part of the company's offerings! Resulting into market growth of their mass produced products also.
- With MP, you're having lost opportunities of additional sales. If some product turns hot unpredictably, you can adapt to such hot items with MC. Eliminating lost opportunities of additional sales.
- In mass-producing firms, changeover times occupy a significant portion of production time and therefore dictate long production runs. To determine the exact length of these runs, the concept of "Economic Order Quantity" (EOQ) is used.

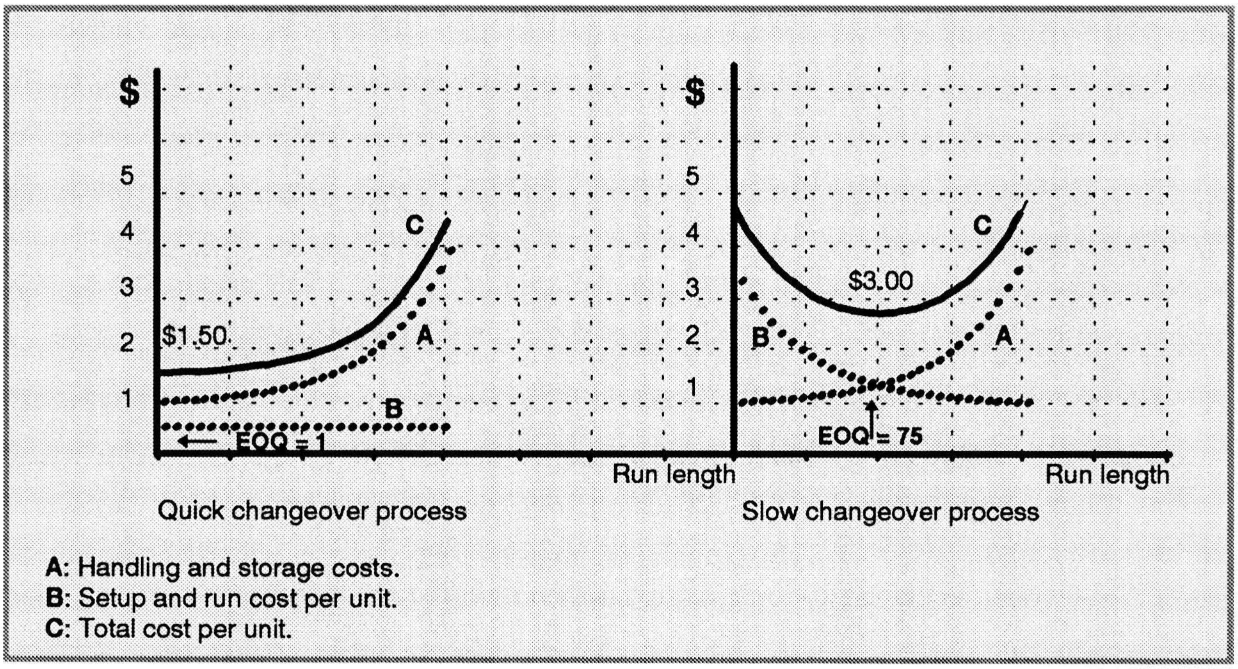


Figure 4.3: The principle of the EOQ in case of drastically reduced changeover costs. (Abegglen & Stalk [01]).

When changeover costs are drastically reduced, the EOQ in figure 4.3 moves down the curve to a run size of one, resulting in much greater variety at much lower costs. Particularly when customer desires are changing rapidly or demand is uncertain, the cost savings of eliminating changeover can be tremendous. (Pine [52]). Mass customisers are specialising on changeover, thereby achieving some sort of economies of scale on changeover. They are capable of producing customised products at the same (or lower) costs as their equal-sized mass producing rivals. Yet, by better satisfying customers, they will be able to sell even *more* products, reducing the cost per unit sold (further).

CIM results in a factory with a theoretical (and some firms an actual) lot size or EOQ of one. It changes significantly the usual volume-variety cost relationships in manufacturing. This is the 'economy of scope' factory that can produce a continuous stream of different product designs at the same (or lower) costs as an equal-sized stream of identical products in the traditional technology factory with economies of scale. (Goldhar & Jelinek [22]).

It will probably appear to be implausible to a current mass producer, that increasing its diversity offered dramatically, can be accompanied by the decrease or even elimination of total changeover time, at the same volume produced. Nevertheless, this is really possible, as the discussions, and examples later on will indicate. A metaphor will perhaps help demystify this apparently contradiction:
The typewriter was invented a very long time ago. A fantastic invention, yet with one huge limitation. Typing bolds, italics, or other fonts, was not possible. The typewriter did not allow for changeover, the solid characters could not be changed. But then, many, many years later, the daisywheel writer was invented, which did allow for changeover. It had a printing mechanism with solid raised characters embossed on the ends of arms, arranged like the spokes of a wheel or the petals of a daisy. If other fonts were needed, the wheel could be changed by another type. Taking some time, just as with changeover in production environments. Pronouncing at that time, that future 'typewriters' would be capable of typing *all* fonts, in *all* manners, even by nearly eliminating changeover, would have been nominated as being science fiction. Just as with pronouncing, a few years ago, the existence of a 'mass producing system', capable of producing an enormous, almost infinite diversity, without losing time due to changeover. Yet, both are reality now! The first, by the emergence of the personal computer, ink-jet, or laser printers, and wordprocessors. Paragraph 4.5 will come back to the innovations, enabling the emergence of both the 'computer typewriter' and the Mass Customisation systems.

- Because manufacturing is demand activated, stocks of end-products will disappear completely. And these stocks will only shift to a limited degree to higher aggregation levels. For today's fast delivery companies, like Federal Express, are capable of providing companies with "inventory-less" direct deliveries of parts and products to and from factories (Anderson & Pine [02]). The total of stocks, and the associating costs, will decrease this way dramatically. Interest costs, insurance costs, handling costs, costs of floor space, etc. The economic inventory, can even be negative! When the customer pays in advance when ordering, and even when paid directly when the product is obtained. The latter, when the period of supplier credit (for instance two months) exceeds the period of manufacturing and delivering the customised product (mostly less than a week!).
- A quite different advantage of the absence of stocks is the ability to make quicker transitions to new technologies. Because, there are no older technology products waiting in inventory to be sold first. Enabling to pick up trends faster also.

> We were probably the first vendor to transition into the new Pentium FPU processor, simply because we didn't have a hundred and a some days of inventory out in distribution that we had to move first. (Rosendo G. Parra, group vice president of Dell Computer Corporation [02]).

(Dell Computer Corporation offers more than 14,000 different configurations of PCs. Production is triggered only after a customer's specific order is received (Yovovich [68])).

- Links, previously fulfilling a search function for the various customers in the value chain, become superfluous. Because the customer is already known to the manufacturer. Leaping over these links enables manufacturers to pass the co-ordination savings onto the customer. A result of the emergence of the virtual value chain, see paragraph 4.5.3, according to Benjamin & Wigand [06].
- Retailers will be able to put more variety in their shelves. In the system of MP, order cycle times are much larger. Forcing the retailers to keep large buffer stocks, at the expense of offering more variety. With MC, this ability will increase sales of the retailer, and the producer.

Further, an indication of the huge opportunities of the principle of Mass Customisation, may also be offered by the amount of companies, where many examples are given of during this report, practising this principle. Renowned companies like Toyota, known for their world-famous process innovations. As with JIT, and the Lean Thinking principle. Perhaps not a very scientific confirmation, yet not less valuable.

4.3 Performance indicator manufacturing systems

MC will, overall, be cheaper in dynamic markets, according to the discussion in the foregoing paragraph. But, in very steady markets, MP can still be more efficient. Markets where competition is small, and everything produced can be sold, like Philips with its light bulbs. So, the discussion demands an indicator, in comparing the efficiency of MP systems and MC systems. For this, in this paragraph a by A. J. de Ron [57] developed performance indicator will be introduced. The Transformation Factor;

(4.1) $TF = E * \rho$.

This Transformation Factor (TF), is the ratio between the average quantity of qualified products obtained during the considered period T, and the maximum quantity of qualified products that could be produced in an ideal situation during the same period (Ron, de [57]).

(4.2) $E = Fm,q / Fm,qm$.

E, the effectiveness of the production system, is the ratio of the average real output flow of qualified products (=Fm,q), and the average maximum output flow of qualified products (=Fm,qm) (Ron, de [57]).

(4.3) $\rho = Te / T$.

ρ, the effective production period, is the ratio between the average effective production period (=Te), and the considered period (=T) (Ron, de [57]).

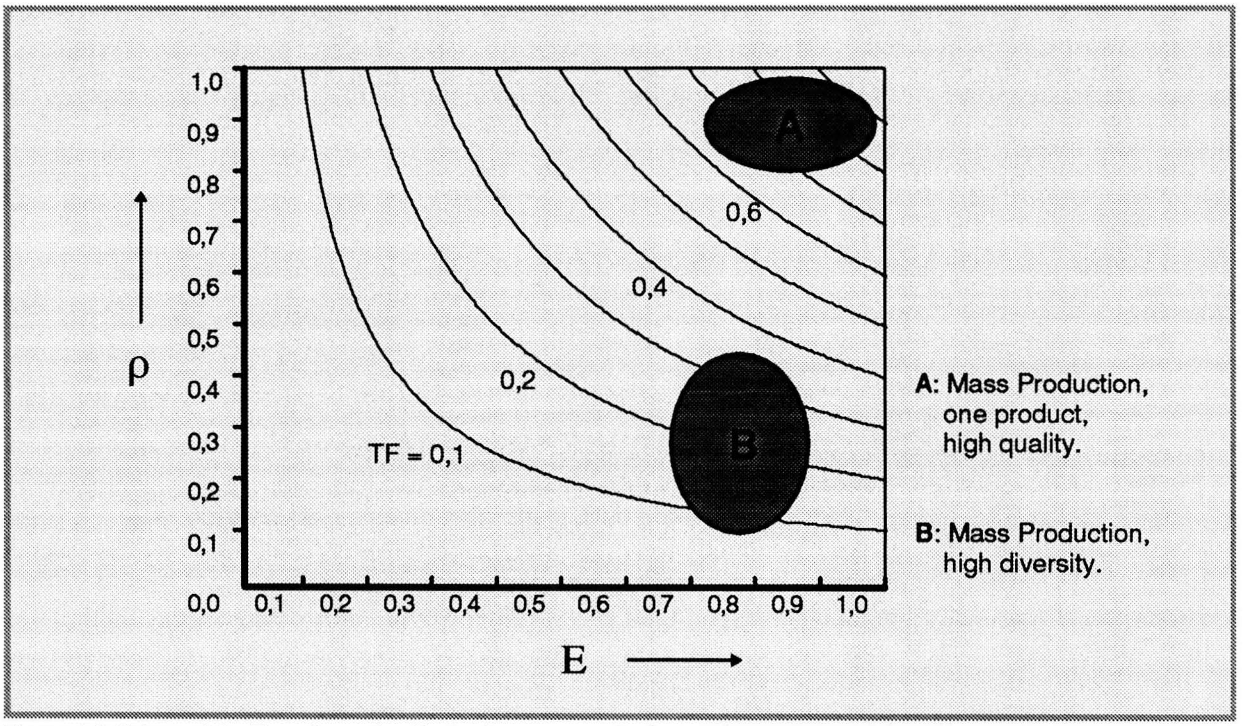


Figure 4.4: Values of the Transformation Factor for mass producing, and mass customising systems, in stable markets.

In this definitions, it is essential to consider quality as defined in paragraph 1.4. Namely, quality is the extent to what a product satisfies each customer. Delivering exactly the kind of product or service each consumer wants, conforming to product specifications, in the right amount, at the right time, and for the right price.

Let's compare the two systems. Traditionally, in stable markets, only the product-based approach of quality is being considered by mass producers. ρ will then be high in these mass producing systems, because the effective production period is almost equal to the available period. This, because there will be almost no losses due to changeover. E is also assumed to be high, because almost all products will be, *technically*, perfect. Technically, there is almost no waste. This will result into TF being very high, see 'A' in figure 4.4, left page.
In this, traditional vision, increasing the offered variety dramatically in reasonably stable markets, will result into a very low ρ. This, because of enormous losses due to changeover. E will be a bit lower than in the case of specialising, optimising the production of just one product. Technical quality must be less when changeovers are made so often, according to this view. Resulting in more waste. Therefore, TF will be much lower, indicating a much lower efficiency, see 'B' in figure 4.4.

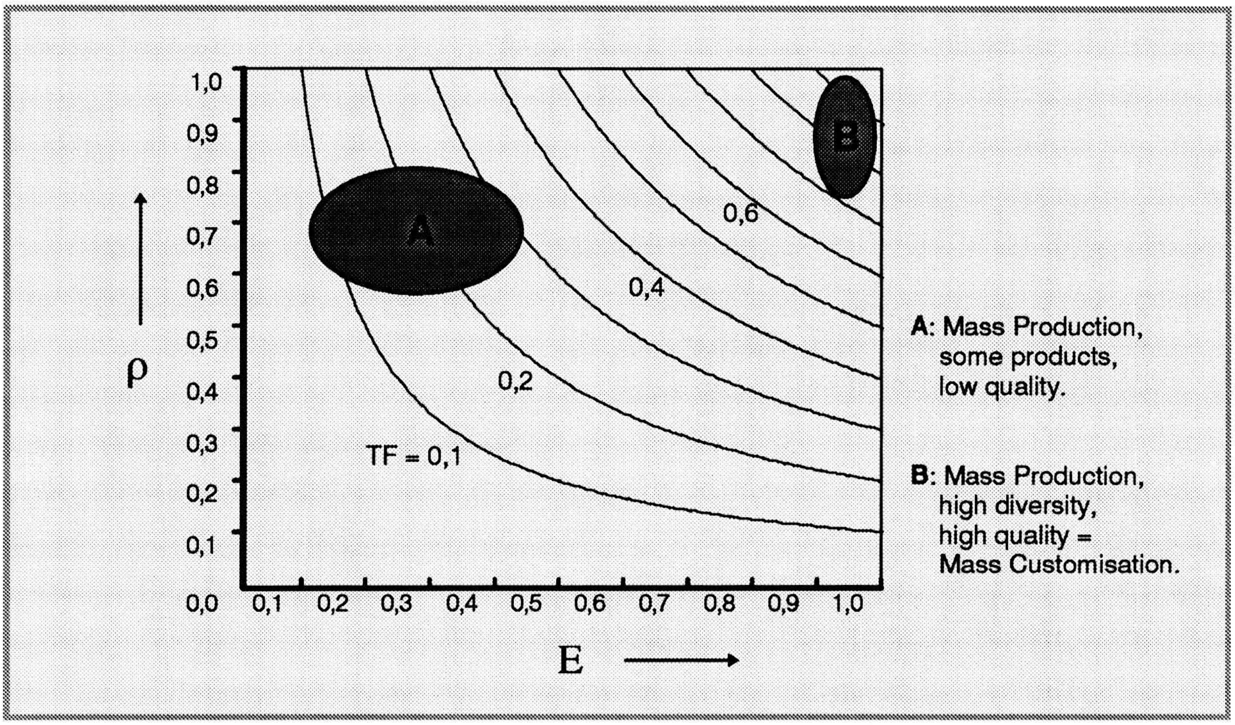


Figure 4.5: Values of the Transformation Factor for mass producing, and mass customising systems, in dynamic markets.

But as discussed, the reality is different. Quality should be considered as stated above. In that case, when competition is extremely high, not all mass products produced, can be sold. Quality of many of these products is actually perceived to be low, as with the Ford Continental. Therefore, the output of qualified products in these markets, is by far not as high as assumed. Resulting into a much lower value of E! Waste is produced, not technically, yet perceived by the customers. In practice, the output of these to a great extent unwanted products, will be turned down. But these systems are not capable of quickly adjusting production, in order to produce the products asked for. Therefore, Te, and ρ accordingly, will not be as high as assumed also. Resulting into a much lower TF as assumed, see 'A' in figure 4.5 above.
MC on the other hand, shows a much more positive picture as expressed. Flexible Production Systems reduce changeover to a minimum, see also paragraph 4.5. Clever product architectures, modularity, CIM technology, etc., make Te, and ρ accordingly, being much higher as assumed. Almost as high, or in some

cases even higher [22], as that of mass producers! Technical quality will also be as perfect as that of mass producing systems. And, if quality considered as stated, all these customised products are especially perceived as qualitatively high. Because products are not only technically perfect, but also wanted, and sold! Resulting into E reaching the value of 1. TF will thereby be extremely high for mass customisers in these dynamic markets, see 'B' in figure 4.5.

This performance indicator helps understanding the competitiveness of MC in dynamic markets. It shows that MC can be extremely efficient in dynamic markets. Where MC mostly, at least presently still!, loses *some* time by changeover, MP appears to lose time by being out of spec! The system is running, yet producing the wrong, unwanted products. The perceived quality is equal to zero! Waste is produced, actually. Only if competition is low, and everything produced will be sold, real dedicated mass producing systems, as with the light bulbs, will still be more efficient.

(4.4) Cost price product = value of all inputs / # products produced.

(4.5) Cost price product = value of all inputs / # products shipped =
value of all inputs / (# products produced - # technical waste).

(4.6) Cost price product = value of all inputs / # products sold =
value of all inputs / (# products produced - # technical waste - # products not sold).

From this discussion, it can be concluded also, that by only calculating the costs of a product related to its BOM (Bill of Materials), as in (4.4), the product's cost price is underrated considerably. Quality related costs should be calculated and taken along also, as in (4.5). But by only considering *technical* poor products as being waste, the cost price will *still* be underrated. Out-of-spec products should be considered as being waste as well, as in (4.6). Also, the inputs of formula 4.6 should include the after sales costs. The costs of satisfying the customer within the period of guarantee offered. Only then, the actual cost price, and efficiency of manufacturing systems becomes manifest.

4.4 Approaches to Mass Customisation

The preceding discussion does not imply that the principle of customisation can not be applied to mature, yet steady markets, as with the light bulbs. Customisation can still be a great, profitable differentiator. After all, any firm that can achieve and sustain differentiation will be an above-average performer in its industry, if its price premium exceeds the extra costs incurred in being unique, according to Porter [55]. Yet, this is not the same as MC. To demystify the different ways of customisation, four distinct approaches to customisation, identified by Gilmore & Pine [21], will be discussed next:

- Collaborative: These customisers conduct a dialogue with individual customers to help them articulate their needs. To identify the precise offering that fulfils those needs. And to make customised products for them. This approach is most often associated with the term MC. The approach dealt with in this report mainly. Collaborative customisers are capable of achieving the gains discussed in paragraph 4.2.

Paris Miki in Japan, the world largest eyewear retailer, spent five years developing the Mikimissimes Design System. First it takes a digital picture of the customer's face. It analyses its attributes as well as a set of statements submitted by the customer about the desired look. The consumer and optician next collaborate to adjust the by the system recommended shape and size of the lenses. They select from a number of options for the nose bridge, hinges, and arms. Then, they receive a photo of themselves with the proposed eyeglasses. Finally a technician grinds the lenses and assembles the eyeglasses in the store within only *one hour*. (Gilmore & Pine [21]).

These customised products can also instantly be provided, by producing it right there, at the point of sale and delivery. Or at least by performing the final, customising production step right there, right then. Then, it's known as Point-of-Delivery Customisation. Men's suits, for example, have long been purchased off the rack and then tailored to the individual within a few days. T-shirts are standard, untailored products, but you can go into almost any shopping mall and purchase one that can be instantly customised with a choice of hundreds (if not thousands) of heat-applied transfer designs.

Englert Inc., of Wallingford, Connecticut, markets a machine that mass-customises gutters as they are about to be put on a house. In the back of a van, a coil of flat aluminium is run through the machine. It forms a continuous, seamless gutter and then cuts it to exact specifications. This process is actually cheaper than the Mass Production of gutters and results in a higher-quality product. Because there's no need for transporting long gutters, and gutters cut to the required length have no seams to leak. Englert sells a similar machine for custom-fit, commercial metal roofs. (Pine [52]).

This is most appropriate for products and services that have one inherently individual characteristic on an otherwise relatively standard commodity. Then, the standard portion can be produced centrally and the customised characteristic can be produced at the point of delivery.

- Adaptive: These customisers offer one standard, but customisable, product that is designed so that users can alter it themselves. This approach is appropriate for businesses whose customers want the product to perform in different ways on different occasions. Lutron's Grafik Eye System, for example, connects different lights in a room and allows the user to program different effects for, lively parties, romantic moments, or quiet evenings of reading. The desired effect can be achieved quickly by punching in the programmed settings, rather than repeatedly having to adjust separate light switches.

In 1995, **Ford Motor Corporation**'s introduced the 'driver-personalisation' system. It allows the Continental to be set up as a 'his and her' car, by even allowing to change its ride characteristics. It allows two drivers to each set his or her own preferences for variable-assist steering effort and ride firmness as well as positions for seats and all three mirrors, autolamp delay settings, instrument lighting intensity, and radio station presets. The preset controls can also include a door lock confirmation noise, automatic express-down driver's window, automatic door locks, automatic tilt-down outside mirrors, and easy entry / exit seats. (Gunneson [24]).

Honda Motorcycle in Japan has developed a range of machines that have a credit-card sized electronic key. This key serves not only as a security device to unlock the steering mechanism, the electronic fuel pump, and other major components. It also contains information that changes the performance of the machine by changing the fuel injection, the timing, the ignition settings, and other parameters. The rider can choose between fast, high performance, economy, town, or mountainous driving, and so forth. The addition of electronic configurability allows the rider to easily reconfigure the machine to meet his or her needs. considerable variety, with many possible choices of width, height dimensions and material. (Maskell [h]).

The new generation of computer programs, particularly games (Nintendo), contain a piece of software called the *parser*. It adapts the program to the kind and amount of user response. As a result, the same game can be completely different for different users with different interests. And Word 7.0 for example, will show a hint for using a short-key combination, after using that specific option 'too' regular.

Matsushita delivers a washing machine with optical sensors to determine the size and dirtiness of the load and microprocessors to select which of *600* different cleaning cycles will clean that load best. (Pine [52]).

The standard, as well as the customisable parts of these washing machines, motorcycles, and wordprocessors are still manufactured by mass producing systems. By making use of mass producing competencies, these companies are capable of fulfilling customer desires much better. But, as Goldhar & Schlie [23] stated: "It is not enough to be differentiated; one has to be differentiated in ways the customer values." The latter is not guaranteed by the Adaptive Customisation approach, for the products manufactured are not actually demanded by the end-user. The manufacturing process is only activated *before* identifying the exact demand of that specific customer. And because of the latter, the gains discussed in paragraph 4.2, will not be achieved by this approach.

■ Cosmetic: Rather than being customised or customisable, a standard product is presented differently for each customer. This approach should be adopted when the standard product satisfies almost every customer and only the product form needs to be customised. For example, the product is displayed differently, the customer's name is placed on each item, etc.

At **Hertz** rental cars, *Gold Program* customers receive, after signing up for the service, the same basic vehicle, but they bypass the line at the counter. They are taken by shuttle bus to a canopied area where they see their name on a large screen that directs them to the exact location of their car. The car's trunk is open for luggage, their name is displayed on the personal agreement hanging from the mirror. And, when the weather demands it, the car's engine is running with the heater or air conditioner turned on. By doing only and exactly what each customer required, Hertz discovered that its Gold service was actually less costly than its standard service. (Gilmore & Pine [21]).

As with Adaptive Customisation, by differentiating products using this cosmetic approach, considerable gains can be achieved because of (much) better satisfying customers. Yet not the most interesting ones, discussed in paragraph 4.2. Because by making services differentiate products, these products are still not produced *after* identifying the exact demand of the end-user.

■ Transparent: These customisers provide individual customers with unique goods or services. Only, without letting them know explicitly that those products and services have been customised for them. This approach is appropriate when customers' specific needs are predictable or can easily be deduced. And especially when customers do not want to state their needs repeatedly.

ChemStation custom-formulates the right mixture of industrial soap, for car washes and cleaning factory floors. It goes into standard 80- to 1000-gallon tanks, which are constantly being monitored. The company learns each customer's usage pattern and presciently delivers more soap before the customer has to ask. The customers do not know which soap formulation they have, how much is in inventory, or when the soap was delivered. They only know, and care, that the soap works and is always there when they need it. (Gilmore & Pine [21]).

Transparent Customisation has many resemblance's with Collaborate Customisation. Even though the customisation is not really triggered by the consumer, the gains of Demand Activated Manufacturing Architectures can be attained this way, at least partly.

In practice, these distinctions turn out to be not always as clear as explicated above. The approaches can also be mixed along each other. But most important is the fact that the gains of the different approaches mentioned, are not all equally far-reaching. If dealing with demand activated manufactured products in this report, the most far-reaching Collaborative Customisation approach is referred to. Yet other approaches could possibly have been mixed with it. This distinction should be noticed when reading. Paragraph 5.2 will come back to the issue of different customisation approaches.

4.5 Innovations achieving Mass Customisation

The development of Just-in-Time delivery, Lean Production, Time-based Competition, and a host of other advances has increased flexibility and responsiveness. And, therefore the ability to increase variety and customisation without parallel increases in costs. Incorporated within these new ways of organising production are some basic innovations that together achieve both Mass and Customisation. The virtual organisation, virtual office, and the flexible design process, have been discussed already extensively. The following five will be discussed next in this paragraph:

- Leveraging of a great number of product variations by mixing and matching different combinations of functional components. (Modular product architectures).
- Producing upon receipt, instead of a forecast. (Demand Activated Manufacturing Architectures).
- Information technology, EDI, Virtual Value Chain (electronic markets).
- Reducing set-up and changeover times, lowering run sizes and the cost of variety. (Computer Integrated Manufacturing, Flexible Manufacturing Systems).
- Applying a new way of management.

4.5.1 Modularity

MC is a synthesis of MP and Craft production. In MP low costs are achieved primarily through economies of scale. Lower unit costs of a single product or service through greater output and faster throughput of the production process. According to Pine [52], the best method for achieving MC, minimising costs while maximising individual customisation, is by creating modular components. Creating modular product architectures can permit the leveraging of a great number of product variations by mixing and matching different combinations of functional components. Economies of scale are gained through the components rather than the products. Economies of scope are gained by using the modular components over and over in different products. A single process produces a greater variety of products or services more cheaply and more quickly. Customisation is gained by the myriad of products that can be configured. A modular product architecture that works this way is the familiar desktop computer.

In paragraph 4.2, the typewriter metaphor has been described. The current 'typewriters', wordprocessors, are capable of typing all fonts, in all manners. Just by clicking a button. This enormous increase of potentials, along with almost eliminating the need of changeover, is among other things due to the application of the principle of modularity. The solid characters of the typewriter have been replaced by modular ones. Such a modular character is constituted by tiny dots. So just *one* module, a dot, is capable of constituting an almost infinite amount of font types and styles. It has even enabled to do completely new things, like 'typing' pictures!

However, the performance of a product can always be optimised and its manufacturing costs lowered by reducing or eliminating modularity. Yet, this is true only for a single product. MC through modularity, with its dual focus on low costs and variety / customisation, will yield better performance and lower costs whenever the task is to create a number of similar but clearly differential products or services. The greater the number of products, and particularly as that number approaches the number of individual customers, the greater the cost and performance advantage of modularity, according to Pine [52].

Modularity reduces design costs in several ways. High commonality reduces the cost of designing product variations. The resulting economies of scale in manufacturing, or greater buyer power in purchasing, results in lower component (production) costs. It also leads to greater experience in producing and using those common components. This may both lower costs of production (learning curve), and improve the reliability. Reducing service and claim costs, and contributing to increased customer satisfaction [52].

To begin a conventional optimising design process, requires a clear definition of both the desired attributes for a new product and the target cost or cost constraint for the product. In dynamic product markets, in which preferences are subject to change, this is likely to be impossible. A product optimised to a specific guess about future market preferences may prove to be inappropriate and a costly mistake, resulting into waste, paragraph 4.3. But modular product designs are capable of meeting a range of product attributes, performance levels, and costs. So modular design requires only a statement of the range of market preferences that may need to be served in the future. Defining a range of market preferences, in stead of a single value, will be reverted to in paragraph 5.4.
With modularity, upgraded products can be introduced rapidly, as soon as improved components become available. Yet, reusing the other components. Fast-followers and imitators may be denied opportunities to profit from introducing "copy-cat" products. This when a modular design firm can continue to introduce improved models before imitators can bring their copies of current-generation products to market.

Sony designed a modular product architecture for its initial M-8 HandyCam 8mm cassette video camera. This enabled Sony to introduce four upgraded models within a 22-month period as quickly as it completed development of key improved components. (Sanchez & Sudharshan [60]).

Bally Engineered Structures provides one of the best examples of modular product architectures. They can create an almost infinite variety. Walk-in coolers, refrigerated warehouses, environmental rooms, etc. But the company produces only one basic modular component, the pre-engineered panel.

Lutron Electronics Company designs and manufactures lighting controls for residential and office environments through modularity. It's far and away the market share leader in lighting controls. Lutron provides over eleven thousand different controls across more than a dozen different product lines. Over 95 percent of its products have annual shipments of fewer than one hundred units. In its electronic lighting systems line, Lutron has never shipped the same system twice. Each and every system is customised to individual specifications, but mass-produced on a single assembly line from standard components. (Pine [52]).

There are many ways to take advantage of modularised components that can be mixed and matched into customisable end products. Pine has taken the work of Karl Ulrich, professor of management at MIT, as the basis for describing a typology for providing suggestions for mass-customising products and services. Figure 4.6 provides illustrations of each of the six different kinds of modularity, to be discussed next.

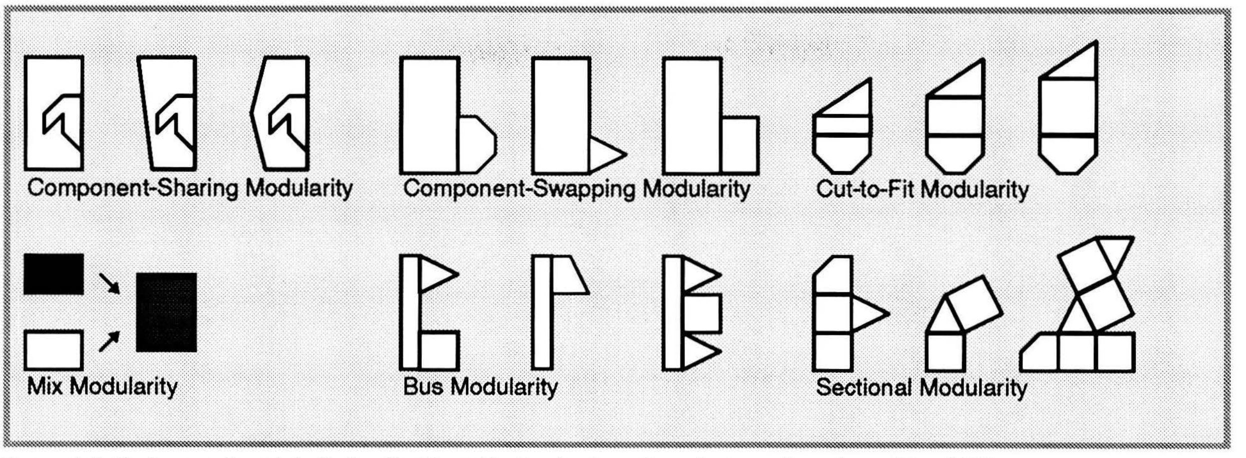


Figure 4.6: Six types of modularity for the Mass Customisation of products and services. (Pine [52]).

■ Component-Sharing Modularity: Here, the same component is used across multiple products, to provide economies of scope at the end-product level, with economies of scale on the component level simultaneously. This form is most important in putting the "mass" into a product line whose costs are rising as fast as, if not faster than, the number of products. This kind of modularity never results in true individual customisation (Collaborative Customisation), except in combination with other modularity types. It's best used to reduce the number of parts and thereby the costs of an existing product line that already has high variety.
Following this philosophy, a medium sized Belgian textile machinery producer was able to accommodate seventeen different models on a single production line. This not only aided productivity, but materials and components purchasing and parts distribution as well. It also made servicing easier for the user and enabled him to cannibalise older vintages to maintain recent models. (Gardiner & Rothwell [19]).
General Electric drastically reduced costs and Time-to-Market by reducing its circuit breaker boxes to replace 28.000 unique parts with 1.275 components shared across 40.000 different box designs. (Dumaine [15]). Sony leveraged more than 160 Walkman models for the US market in the 1980s from only five modular platform designs. (Sanderson & Uzumeri [61]).

Ford UK has had *half* the number of basic models of British Leyland but about *twice* as many derived variants. Ford was able to achieve a considerably wider market coverage while maintaining a highly disciplined production base. With half the number of basic models, Ford almost halved its production problems while at the same time greatly simplifying its parts and servicing operations. The issue here is that makeability should extend across whole product ranges, or families of products, and should be an important factor in strategic decisions determining the choice and range of products. Interrelationships and possibilities for production synergy should not be neglected. (Gardiner & Rothwell [19]).

■ Component-Swapping Modularity: This method is the complement. Here different components are paired with the same basic product, creating as many products as there are components to swap. MCA Inc., a subsidiary of Matsushita, is investigating mass-customising movies by allowing patrons to individualise the experience in specially built virtual reality theatres. Customising services around standardised products or services can also be thought of as Component-Swapping Modularity.
When there are an infinite number of components to be swapped, or at least as many as there are people to buy that product or service, true individual customisation comes.

Create-A-Book® is a line of children's books personalised to individual boys and girls. Over a dozen professionally written and illustrated generic titles provide the basic products for this company. The buyer, usually a relative, is asked personal questions about the recipient (name, mother's name, place of birth, etc.) This provides the components to swap into the basic product. A personal computer sprinkles the information appropriately throughout the text. Within *fifteen minutes* the pages of the book are printed on a laser printer and bound into a normal book cover. For $13,95, a price similar to that for quality titles available in retail stores, children receive their own customised book. (Pine [52]).

■ Cut-to-Fit Modularity: Custom Cut Technologies' process for mass-customising suits clearly cuts to fit each of its components (jacket body, sleeves, lapels, etc.). Peerless Saw can easily laser-cut to vary the dimensions of any saw. At self-service salad bars, customers can choose the portion they desire of each ingredient. Cut-to-Fit Modularity is most useful for products whose customer value rest greatly on a component that can be continually varied to match individual wants and needs.

The **National Panasonic Bicycle** company, a subsidiary of **Matsushita** in Japan, provides individually customised bicycles through Cut-to-Fit and Component-Sharing Modularity combined. Its factory is ready to produce any of 11.231.862 variations on 18 models of racing, road, and mountain bikes in 199 colour patterns and about as many sizes as there are people. The process starts with a shopkeeper who determines a customer's model, colour, and design preferences. Then precisely measures him or her on a special frame for the cut-to-fit components, because riders come in different proportions not just different heights. All the specifications are faxed to the factory, where a computer creates custom blueprints for both craftsmen and robots. The latter measure and cut each piece of the frame to fit the individual's measurements, weld the pieces together, and apply the base coat of paint. The skilled workers perform most of the assembly work and all of the final touches, including silk-screening the customer's name on the frame. (Moffat [46]).

When the system was introduced in 1988 there were 11.655 total variations to choose from. In 1990 the range was already over 11 million. Such achievements depend on a very high degree of manufacturing competence. In 1992 they sold only 15.000 customised bicycles, but at an average cost only 15% above their best mass produced bicycle. Most important, National Panasonic Bicycle has proved that MC can be a reality, not just a utopia! When they exposed their plan to industry experts just a few years ago, they were politely assured that MC was impossible. Now Matsushita has developed the competence necessary to support MC, and not only at the NPB. The question is *when* the pilot plant will be scaled up, providing truly mass customised bicycles at even lower costs. This will give NPB an unbeatable offering to an even larger market. And, which of these electronic giant's plants will follow?
When Matsushita began providing individually customised bicycles in just a few days, many customers reacted negatively. Delivery was just to quick for them to believe the product was really custom made. To completely satisfy its customers, the company had to delay the delivery of its bicycles to two weeks!

■ Mix Modularity: This type of modularity can use any of the above types, with the clear distinction that the components are so mixed together, that they themselves become something different. When particular colours of paint are mixed together, for example, those components are no longer visible in the end product. Mexican restaurants create an incredible variety of meals by mixing relatively few components: tortillas, beans, various meats, and various sauces. The key factor in determining if you can take advantage of mix modularity is recipe. Anything with a recipe can be varied for different markets, different locales, and indeed for different individuals. To reach perfect customisation, requires moving from processing recipes according to a predetermined plan to a Process-to-Order operation. And then economically reducing the batch size to one (EOQ=1).

■ Bus Modularity: This type of modularity uses a standard structure that can attach a number of different kinds of components. It allows variation in the type, number, and location of modules that can plug into it. The key to using Bus Modularity is of course the existence of a bus, as with computers. If a product or service has a definite standard but changeable structure, break it up. This by first, defining the product architecture or service infrastructure that is really required for each customer. Second, modularising everything else into the components that can be plugged into that standard structure.
The automobile could take advantage of bus modularity. The basic platform chassis and wiring harness that connects all of the electronics can provide the bus structure, where everything else can plug into. GM's Pontiac Fiero, with a modularised body and other components, has come closest to this concept in actual production. And Chrysler has proposed a production concept consisting of twenty-eight modules.

Nissan appears to be the company that wants to first mass-customise individual automobiles. Its vision for car manufacture is the five A's. Any volume, Any time, Any body, Anywhere, and Anything. Nissan is working toward it through a joint university-industry research program in Japan known as Manufacturing 21. Participants in this program foresee full Mass Customisation of automobiles in the first year of the twenty-first century (*2000*!!!) utilising not only all the different types of modularity discussed so far, but also Time-Compression, Point-of-Sale Manufacturing, Customisability, etc. (Emrich [16]).

Reducing the time and cost of new model development and start-up is the number one priority of the Japanese auto industry heading the 1990s. Many assembly ideas have been considered. All of the most promising ones assume final assembly of cars from large modules with each module being subassembled on a short line. Cars would have to be designed with structural modules that can be subassembled in different locations. Then brought together for final assembly of the structure, followed by attachment of the body panels. The external shape of the completed body is thereby partly independent of the form of the structural framework. If the design could ingeniously allow for dimensional variations, final assembly might even be done at the dealership.

In Japan, **Toyota** is reportedly offering customers *five-day* delivery. From the time the customer personally designs his / her own, customised car (from modular options) on a CAD system, through order processing, scheduling, manufacture, testing and delivery. The CAD system is in a dealer showroom or in the customer's own home via a travelling salesman. (Goldhar & Schlie [23]).

New technology is not developed for each project. More often it is a matter of cleverly combining existing elements. Real custom work is far to costly. It's like saying 'I need a car with such and such specifications, and I will have it made to order.' That is out of the question. (H. Keizer, director of Philips Sales Organisation, supplying complete systems for furnishing buildings (Mastenbroek [44])).

The examples of Nissan and Toyota prove the contrary. Indeed, customisation can not be achieved just by combining existing elements. Nor, affordably, by designing all new elements for each individual car.

The usual car architectures do not account for far-reaching customisation. For this, completely new modular architectures should be designed. A basic platform chassis and wiring harness, where everything else can plug into, can, for example, provide such a modular bus structure for cars. Commonality should be achieved at a modular level. New, very fast, production technologies, will affordably produce, among other things, the customised body work. Besides, when Keizer's statement was made in 1991, the Manufacturing 21 project was already started. The reports of Toyota offering their customised cars, already stems from 1991 also, therefore engaged in MC for already many years! It seems just a matter of time, how long it will take before cars are offered *apparently, completely* customised. This by applying the different modularity types, as well as possibly technical innovations, new materials, presently unknown or even still not imaginable.

■ Sectional Modularity: This type of modularity provides the greatest degree of variety and customisation. Sectional Modularity allows the configuration of any number of different types of components in arbitrary ways, as long as each component is connected to another at standard interfaces. The classic example is LEGO building blocks with their locking-cylinder interfaces. The number of objects that can be built with LEGO is limited only by the imagination.

> Agfa uses a relatively new technology in the computer industry known as object-oriented architecture. This technology has the potential for revolutionising software development through the concept of reuse. So moving it from its traditional Craft Production orientation to the new frontier of Mass Customisation. In object-oriented systems, a piece of program code is a highly modular object. With the interfaces between modules simply and completely defined by the object type. Objects can be reused any number of times in any number of different programs. Creating Sectional Modularity that allows the quick development of radically different applications. In practice, object-oriented technology has not progressed to the point where full applications can be developed completely from modules without creating any new code from scratch. (Schwartz & Verity [62]).

The quotation above (1991), is already out-dated. At this moment, object-oriented programming has already become a standard in developing software. For instance Windows 95, and all of its applications, are all object-oriented.

Drawbacks of modularity; while the opportunities for using all six types of modularity are tremendous, there are potential drawbacks that may cause particular problems in some organisations:

■ Customers may perceive some sets of modularised products as being overly similar. In the 1970s, General Motors was heavily criticised for sharing too many components among models, making them look too much alike. So it is important that design take into account what customers find most personal about a product or service, like body styling in a car, and ensure that those areas retain the most variability, preferably obtaining individual customisation [52].

■ Competitors can reverse-engineer modular designs more easily than unique designs. So copied Tyco Toys the Lego's design, and made Lego-compatible building blocks.

> The same properties that make a design easy to reuse by the original manufacturer make the design easy to copy by competitors. (Ulrich [64]).

According to Sanchez [60], adopting modular product architectures for mass customising products, will have a strategically significant impact on the design of the organisation. Because the interface specifications that define how developed components must work together will be developed first. Therefore, decoupling component designs in modular product architectures also decouples processes for developing those components. This allows those processes to be carried out concurrently, autonomously, and distributively by various developers, enabling the formation of virtual organisations. And virtual enterprises, discussed in paragraph 3.2 enable modular product architectures.
So according to Sanchez [60], modular product architectures make possible new product development processes. Processes, requiring fewer management resources, improve development speed, encourage greater innovation at the component level, and allow access to an enlarged network of component development resources.

- Reduced management resources: The specified component interfaces in a modular product architecture create an information structure that defines the required output of each component development process. Rather than trying to directly manage processes during component development, the interface specifications will be managed. Then there is little or no need for allocation of managerial resources by the product-designing firm to supervise component development processes. Reductions in the management and technical staff required to develop modular products increase the flexibility of a firm to respond to a larger number of product development opportunities.

> Using a modular product architecture has contributed to **Chrysler**'s ability to develop better cars much faster. With reductions of *40 percent* or more in the number of people required for development projects. (Holmes [29]).

- Improved speed of development: Development of components consumes the major time required for overall product development. So concurrent development of components for a modular product design can significantly shorten total development times. A faster development cycle improves the flexibility of a firm to respond quickly to new market opportunities. This can have considerable economic value, especially when the opportunity costs of being late to market are high.
- Improved ability to innovate in component development: Autonomous component development processes may also lead to greater involvement of customers and new suppliers in component development. Decisions affecting component design do not involve other component development groups. Those decisions can be made with reference only to that component's specifications. A complicated decision-making process is avoided. Improving flexibility in gathering and incorporating new market information and new component technologies in creating new products.
- Distributed product development: Fully specifying component interfaces improves the ability to distribute component development tasks to groups within its own internal network of resources. Or to the most capable component development firms, wherever those firms may be located. This way the firm can draw on more, and more diverse, component development expertise. The ability to make use of an enlarged pool of development firms may reduce the time and cost of product development projects.

4.5.2 Demand Activated Manufacturing Architectures

In the system of MP, customers are at the end of the value chain. They are sold whatever the production function produces. Black Fords for instance. In the system of MC, customers are also at the beginning of the value chain, which exists to produce what customers want and value more highly than the money they are asked to give in exchange. In effect, the chain really bends around to become a loop, with customers

an integral part of it, creating what futurist Alvin Toffler has labelled the rebirth of the prosumer. A producer and consumer in concert defining and producing the product.
Today, for example, the vast majority of cash withdrawals take place by means of Automatic Teller Machines (ATMs). IKEA promises customers to deliver well-designed products at substantially lower prices, if they take on certain key tasks traditionally done by manufacturers and retailers (the assembly of products and their delivery to customers' homes). IKEA wants its customers to understand that their role is not to consume value but to create it. Customers are also suppliers (of time, labour, information, and transportation). Customers become prosumers (Normann and Ramirez [47]).
Other examples are the self-service gas stations, or the self-service salad bars, where customers can choose the portion they desire of each ingredient. It's not the producer who activates the production system here, refuelling or 'producing' a salad, but the consumer (prosumer). This way the production organisation becomes demand activated. It encourages more customer interaction and information, faster cycle times, and greater variety and customisation.

The definitely most profound revolution in MC is the ability to design, schedule, and make exactly what the customer wants, when the customer wants it. These Demand Activated Manufacturing Architectures (DAMA), mean you can throw away the sales forecast and simply make what customers actually tell you they need. Rather than pushing unwanted products, like black Fords, onto the customer. The advantages of DAMA have been discussed already in paragraph 4.2.
DAMA is different from the Assemble-to-Order, and Produce-to-Order systems, known and applied for already a long time. The orders in such order driven systems contain many products of the same type, requested within a certain length of time. The demand in DAMA, is the instant request for one specific product by one specific end-customer.

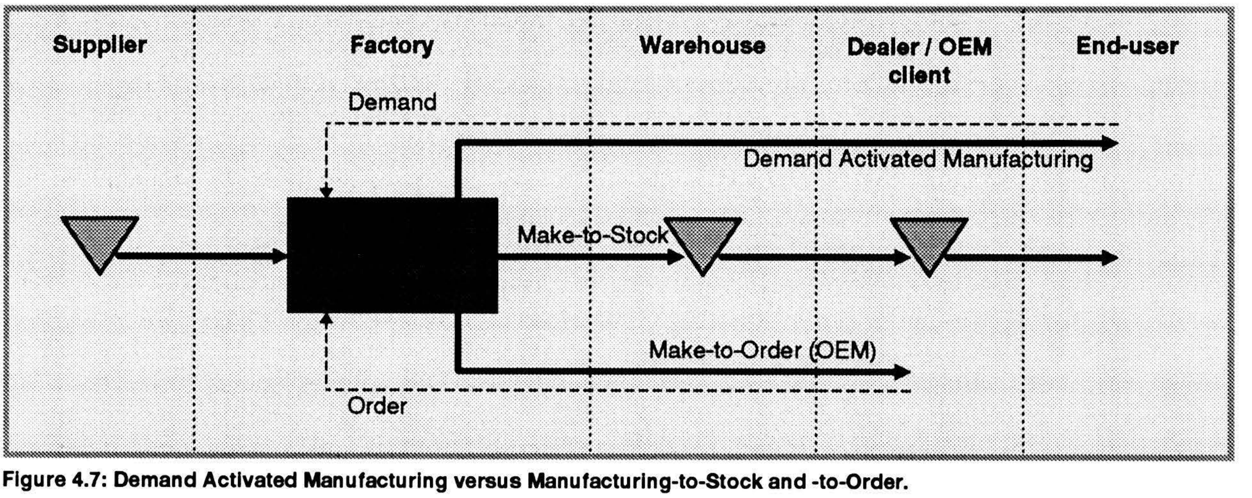


Figure 4.7: Demand Activated Manufacturing versus Manufacturing-to-Stock and -to-Order.

Figure 4.7 shows the difference between order driven and demand driven manufacturing. The latter is really a lot more demanding of an production organisation, than the conventional Manufacturing-to-Stock and even Manufacturing-to-Order systems.

In the USA, there's a recent example of an enormous ungoing project, applying DAMA in the entire apparel industry. This DAMA project was created under the umbrella of the American Textile Partnership (AMTEX). DAMA has to facilitate fundamental improvements in the competitiveness of the U.S. Integrated Industrial Complex (ITC). Currently, over 30 of the US's leading companies have committed to be partners. (Chapman & Lovejoy [a]). The impulse for the project is the domestic U.S. ITC's loss of marketshare during the period of 1980 to 1994 to foreign producers. This shrinking marketshare has also

caused follow-on losses across the industry because of interdependencies among the industry's production components.
DAMA will provide companies in the industry with the means to acquire and exchange information rapidly, allowing them to predict and/or adjust their Flexible Manufacturing Systems to changes in demand. It will provide companies in the U.S. ITC with the means to rapidly acquire needed business and product information. This access to information, has to, and probably will, give these manufacturers a distinct advantage over their foreign competitors [a]. According to Chapman & Lovejoy [a], increased competitiveness has to result from:

- Reducing cycle time through the integrated textile pipeline.
- Eliminating non-value-added process steps in the pipeline.
- Reducing inventory size and increasing turns through the pipeline.
- Improving product development effectiveness through advanced communication techniques.

4.5.3 Information technology and the Virtual Value Chain

Creating value has been described as a model called the value chain, see paragraph 2.2.1. Traditionally, the producer, wholesaler, retailer and consumer are the value chain stakeholders. New organisational principles like Time-based Competition, DAMA, and MC will, combined with the ever improving cost performance of information technology, have profound effects on this traditional value chain.

According to Benjamin, Malone and Yates [05], there are three main effects of information technology on markets, resulting into the emergence of the Virtual Value Chain (VVC):

- The electronic communication effect; technology allows more information to be communicated in the same amount of time, at a much lower cost. This enables for example the transmission of enormous amounts of data in a relative short time, as with video-conferencing.

- The electronic integration effect; that is, coupling more tightly (co-ordinating) value-adding stages of production and distribution across different organisations.
  Network technologies provide the links for a new pattern of transactions. DAMA implicates that the final consumer is already known to the manufacturer, as he still has to start production. So in these architectures, manufacturers leap over intermediaries, reaching the consumer directly. Activities which previously created value by providing a search function for the consumer, as with wholesalers and retailers, disappear. Many of these activities will be substituted by much less costly virtual ones.

- The electronic brokerage effect; computers and communication technologies allow many potential buyers and sellers of a given good to be matched in an intelligent way. The consumer can easily access a sufficient number of single-source sales channels through a market choice box or an interactive agent to search for manufacturers. The user interface owner will like to appropriate a portion of the resulting value chain and market-maker savings rather than share them with the consumer. But still, part of the savings will be passed onto the final consumer, resulting in lower prices. The principle of electronic sales has been discussed thoroughly in the Master thesis of colleague student H. Darwinkel [13].

Peapod, is a supermarket home shopping service, available in San Francisco and Chicago. Customers (2500 and 5000 resp.) pay $30 per month for the shopping service. Using a workstation (Windows environment), the customer can shop by aisle or by item name, develop personal lists, select delivery times. They can specify items, for example four bananas, two grean and two ripe. Peapod's marketing manager suggests that people can pay for the service just by eliminating children's "bribes" for good behavior while shopping. (Benjamin & Wigand [06]).

Companies like Matsushita and Toyota understand the capabilities of information technology in changing the traditional ways of organising production into new ones, like MC. As with the introduction of the telephone, lorries, and aircraft's, the real benefits were generated only after changing the existing, old ways of working completely. Not just by improving the old ways by applying these innovations!
Advances in the speed, capacity, effectiveness, efficiency, and usability of information and tele-communications technologies constantly lower costs of increasing differentiation in service as well as manufacturing industries. The instant application of information throughout a firm's value chain allows it to respond quickly to changes in demand and designs. According to Pine [52], whole new classes of mass customised products and services are enabled by such advancing technologies as computerised databases that can respond instantly to individual requests for information.

The appearance of the VVC redefines economies of scale. Small companies are now allowed to achieve low unit costs for products and services dominated by big companies. Formerly, such small companies couldn't afford to build a shop in every town. But now they virtually can, even in every house! And digital assets are not used up in their consumption. Companies that create value with them may be able to reuse them through a potentially infinite number of transactions.

Summarising, according to Benjamin & Wigand [06], opportunities and risks of the VVC are:

- Benefits to the consumer (free market access to all suppliers, paying interconnection costs, maximum choice at lower price).
- Lower co-ordination costs (reducing intermediary transactions and unneeded co-ordination because of electronic transactions directly with the consumer).
- Lower physical distribution costs (shorter value chain eliminating related costs and information will be transmitted electronically, so much lower electronic distribution costs will be substituted).
- Redistribution and potential reduction in total profits. (compensation by increasing volume?).

4.5.4 Enabling technologies of Mass Customisation

In MC, new technologies are playing a key role. Technologies like, CAD/CAM, CIM, robots, FMS, EDI, etc. Without these, MC would never be possible. Especially the rapid cost performance improvement of information technology makes MC more competitive day by day. The processing capacity per unit of cost for microprocessors doubles every 18 months. This is also another enabler of the current 'typewriters' mentioned, besides modularity. However, these technologies are far less important than the achievement of a simplified, responsive, and effective organisation, previously described in chapter 2. Without first achieving such fundamental improvements, any technology tools will only give minimal benefits.

CAD/CAM allows design modifications, even new designs, to be quickly developed. The manufacturing requirements are automatically generated from the design specifications. CIM links all the firm's operations related to the production function into a single, integrated system. The system is fast, responsive, flexible, and very low cost at high volumes. These manufacturing technologies can yield economics of scale and scope simultaneously. Unit costs go down with the greater number of products manufactured because that increases the volume of the entire operation. (Pine [52]).
Or, as Goldhar & Schlie [23] stated: "CIM technology greatly enlarges the scope of differentiation possibilities that can be achieved through manufacturing. And, at the same time, CIM technology, because of its flexibility, lowers the cost penalty for differentiation achievable through manufacturing. In some cases may lower it on a par with or below the costs of a large-scale competitor pursuing a cost leadership strategy with dedicated automation technology!"
In manufacturing industries, Computer Numerical Control, Direct Numerical Control, and industrial robots greatly increase manufacturing flexibility by controlling parts manufacture through software

programming. Flexible Manufacturing Systems (FMSs) extend this by allowing all members of a family of parts to be manufactured at will and at random. Within a predetermined envelope of variety, there are no cost penalties for manufacturing any one part versus another. Yielding a manufacturing system that can quickly respond to changes in demand.
A Flexible Manufacturing System (FMS) is an integrated group of Computer-Numerically Controlled and robotised workstations linked by automated material-handling systems. In principle, an FMS combines the specialist advantages of a job shop for small-batch production with the scale advantages of a flow line for high volume production. An FMS is flexible in that it functions as a general tool capable of producing a range of specialised products by simply changing the instructions.

FMSs allow Japanese manufacturers to build up to *eight* different models on *a single* assembly line. In the United States most assembly lines and some entire plants are dedicated to a single model. If the model isn't selling, the line shuts down . . . US auto executives must plan only models that can sell at least 200.000 units. In contrast the **Mazda Miata** can sell 20.000 units in the United States without taking a financial bath. (Bateman & Zeithaml [03]).

According to Jaikumar [32], an FMS eliminates the barriers of rigid transfer machines and manual set-ups to combining the variety of a job shop with the volume of a Mass Production plant. Obviously the stand-alone general machines of a job shop offer more flexibility than an FMS, but they offer none of the scale advantages of long runs. Jaikumar [32] studied 35 FMSs in the United States and 60 in Japan, a sample that represented roughly half of the installed capacity in each country at that time. Table 4.1 illustrates the increase in performance of a Japanese factory after the introduction of such an FMS.

Table 4.1: Performance of a Japanese factory before and after the introduction of Total Flexible Automation (Jaikumar [32]).

	Before	After
Types of parts produced per month*	543	543
Number of pieces produced per month*	11,120	11,120
Floor space required (m^2)	16,500	6,600
CNC machine tools	66	38
General purpose machine tools	24	5
Total	**90**	**43**
Operators	170	36
Distribution and production control workers	25	3
Total	**195**	**39**
Average machining time per part (days)**	35	3
Average assembly time per unit (days)**	14	7
Average final assembly time per part (days)**	42	20
Total	**91**	**30**

* To make the comparison useful, these figures are held constant.
** This includes time spent in queue.

Used properly, FMSs, unlike the specialist rigidly linked machines of Mass Production, will not require large production plants even in assembly. The minimum efficient scale for FMS operations is a cell of roughly six machines and fewer than a half a dozen people. That's the new reality. (Jaikumar [32]). Together with the predescribed effects of the VVC makes that the competitive advantages of the large companies in respect of their small rivals, as a result of their economies of scale, fade away.

Electronic Data Interchange (EDI) is the electronic exchange of machine-readable data in standardised formats between one organisations computer and another. It replaces a host of paper forms which constituted the primary communications link between manufacturers, suppliers, wholesales, distributors

and retailers. A link for ordering, invoicing, shipping and inventory control. EDI reaches far beyond bar-code scanning and sophisticated Point-of-Sale (POS) terminals. It encompasses hand-held laser scanners, satellite link-ups and wireless systems using in-store radio frequencies.
EDI accomplishes cost savings by eliminating volumes of existing paper-based transactions and reducing clerical work, paper and postage. It also increases productivity by faster processing, with fewer data entry errors, of purchase orders, invoices and other standard paper-based communications from days to minutes, in combination with implementing quality improvements.

EDI's powerful potential can be seen by looking at what Federal Express, American Airlines, and UPS have accomplished using it. They track millions of items, from millions of random places going to a set of final distribution points over thousands of miles in trucks and aircraft's. And they know where each item is in the process!
EDI provides the smaller guy a common way to do business where larger guys would normally have an advantage. Because, EDIFACT, Uniform Code Council, and the National Retail Foundation have laid out standards, the smaller players can share the advantages that bigger guys have.
EDI is also an integral element in the implementation of Quick Response, or Time-based Competition. This by speeding up the flow of information between suppliers and customers and allowing each to keep inventory levels to a minimum.

Ten years ago it took **Target Stores** almost *19 days* to put a product from a paper-based purchase order (PO) on the shelves. Today that cycle time has been reduced to under *5 days*, all because the mass retailer demands that its vendors send electronic orders and advance electronic shipping notices to all its carriers. And from its carriers, Target requires status messages of what's coming in and when it will arrive. (Belle, van [04]).

4.5.5 Management

However, of equal if not greater importance in achieving both low costs and customisation are advances in management. Jaikumar concluded after studying 95 FMSs, that FMSs installed in the United States show an astonishing lack of flexibility. The average number of parts made by an FMS in the U.S. was 10, in Japan the average was 93. Seven of the U.S. systems made just 3 parts. The U.S. companies used the FMSs the wrong way. For high-volume production of a few parts rather than for high-variety production of many parts at low cost per unit. Thus the annual volume per part in the U.S. was 1727; in Japan only 258. Nor have U.S. installations exploited opportunities to introduce new products. For every new part introduced into a U.S. system, 22 parts were introduced in Japan. See also table 4.2 below.

Table 4.2: Comparison of FMSs studied in the United States and Japan (Jaikumar [32]).

	United States	Japan
System development time (years)	2.5 to 3	1.25 to 1.75
Number of machines per system	7	6
Types of parts produced per system	10	93
Annual volume per part	1,727	258
Number of parts produced per day	88	120
Number of new parts introduced per year	1	22
Number of systems with untended operations	0	18
Utilisation rate* (two shifts)	52%	84%
Average metal-cutting time per day (hours)	8.3	20.2

* Ratio of actual metal-cutting time to time available for metal cutting.

It is how the equipment is used that is important. Success comes from achieving continuous process improvement through organisational learning and experimentation. In Japan, operators on the shop floor make continual programming changes and are responsible for writing new programs for both parts and the system as a whole. Competition shifts from economies in running a plant to planning it, and only people who are also involved in operations can gain the experiential knowledge required to make the new technology perform to its full potential.
The American firms that separated planning from doing cannot generate the new knowledge required. Engineers that set up the FMS cannot be faulted. Their job is to set the system up, not to run it. Reliability and flexibility can only be developed in the process of operations. Designing flexibility into the machines is only part of the job. (Jaikumar[32]).

> The new role of management in manufacturing is to create and nurture the project teams whose intellectual capabilities produce competitive advantage. What gets managed is intellectual capital, not equipment. (Jaikumar [32]).

A Computer-Integrated Manufacturing (CIM) strategy, envisages a factory of the future in which (direct) human labour is replaced with the computer. But the advantages of computerised manufacturing depend upon the capacity of the operators to use them effectively. FMSs are a good servant but a bad master. Thus MC requires a fundamentally different management approach, as in MP systems. This will be reverted to extensively in chapter 5.

4.6 Decoupling of product and process life cycles

With MP, the product and process life cycles have been coupled. Breakthrough product developments necessitate switching over to a new product family. Then the old process also gives way to a new process, designed specifically to make production of the new product as efficient as possible, figure 4.8.

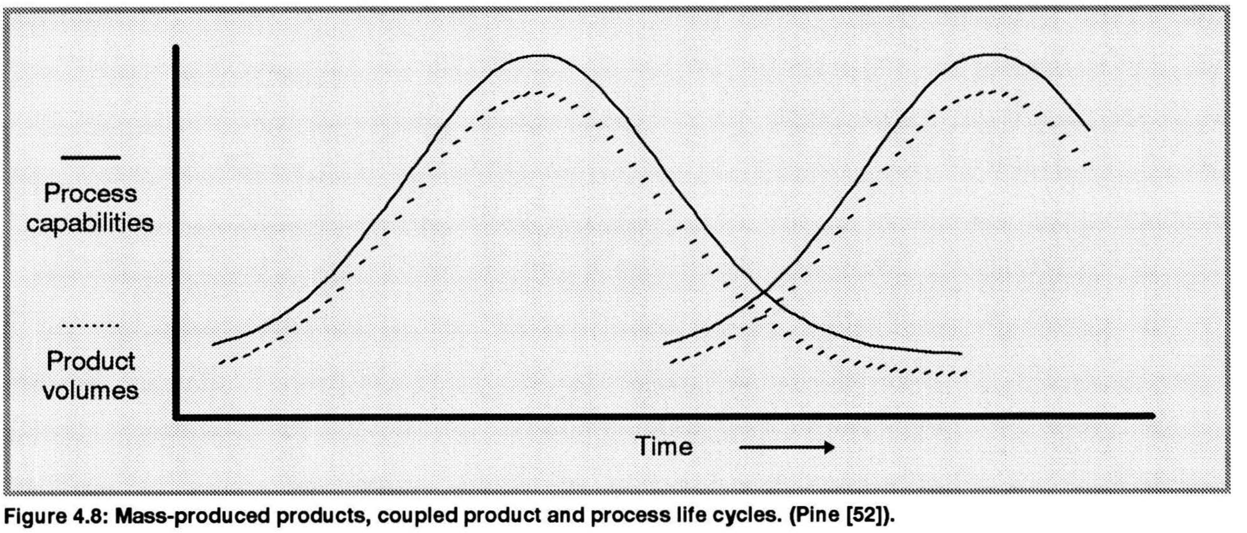


Figure 4.8: Mass-produced products, coupled product and process life cycles. (Pine [52]).

With MC, a key advantage is the decoupling of product and process life cycles. The importance of individual products decreases as the same processes can be used to develop, produce, market, and deliver many products and product families. This is shown in figure 4.9, where the long-term, stable processes allow the creation of a dynamic flow of products and services. As product life cycles decrease and the flow of products and services increases, a company's stable process base provides a distinct net advantage over its competitors. Particularly if they still have coupled product and process life cycles that require significant resources for the development of new processes for every major new product [52].

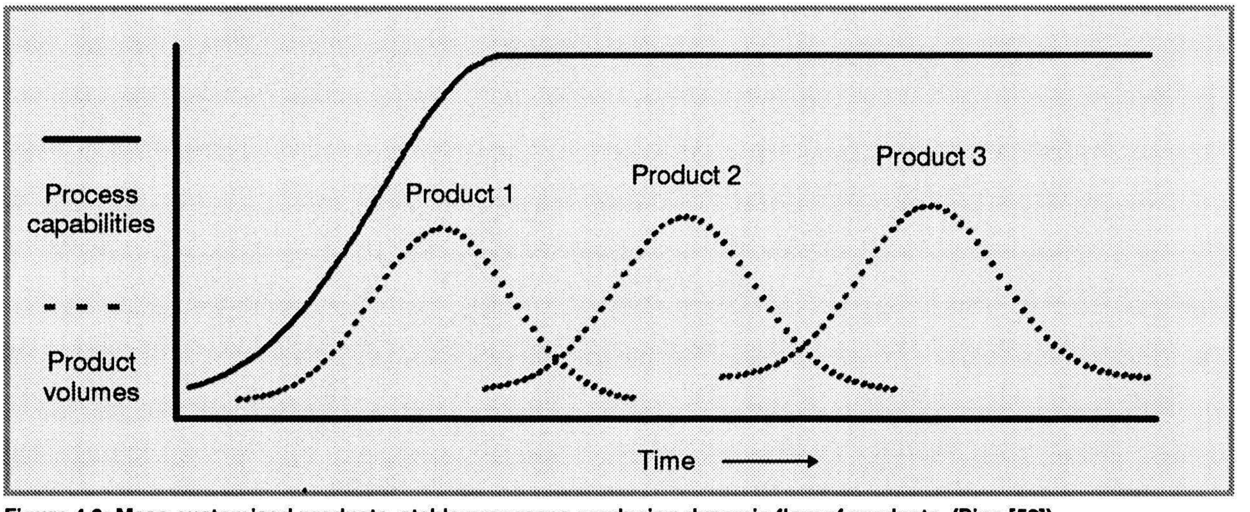


Figure 4.9: Mass-customised products, stable processes producing dynamic flow of products. (Pine [52]).

However, as more companies move into the new frontier, this advantage will lessen. Companies striving for new advantages will have to switch to new processes to move ahead of the competition. While their competitors are imitating their old processes, the best companies will already be moving on to their next set of processes, and the ones after that, and so on [52]. This results in the situation seen in figure 4.10.

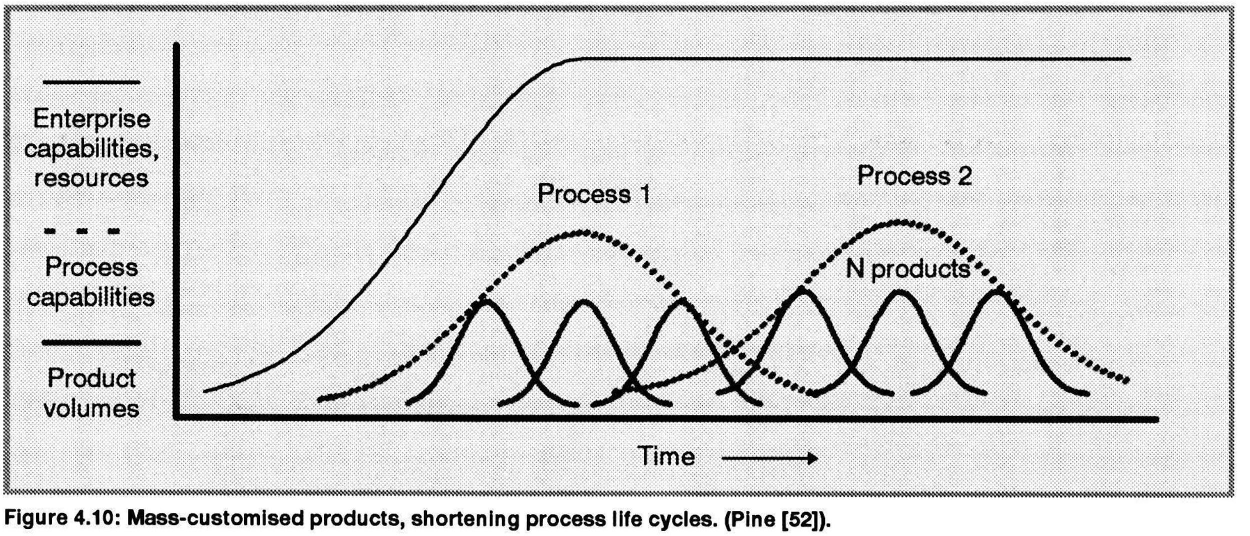


Figure 4.10: Mass-customised products, shortening process life cycles. (Pine [52]).

Today companies gain advantage by shortening product life cycles with constant product innovations, providing both low costs and great product variety and customisation. As companies today are moving to the mass customisation of products, tomorrow they will be moving to Mass Customisation of processes. Uniquely suited to new market opportunities. Companies will gain advantage through shortened process life cycles with constant process innovations and great process variety and customisation [52].

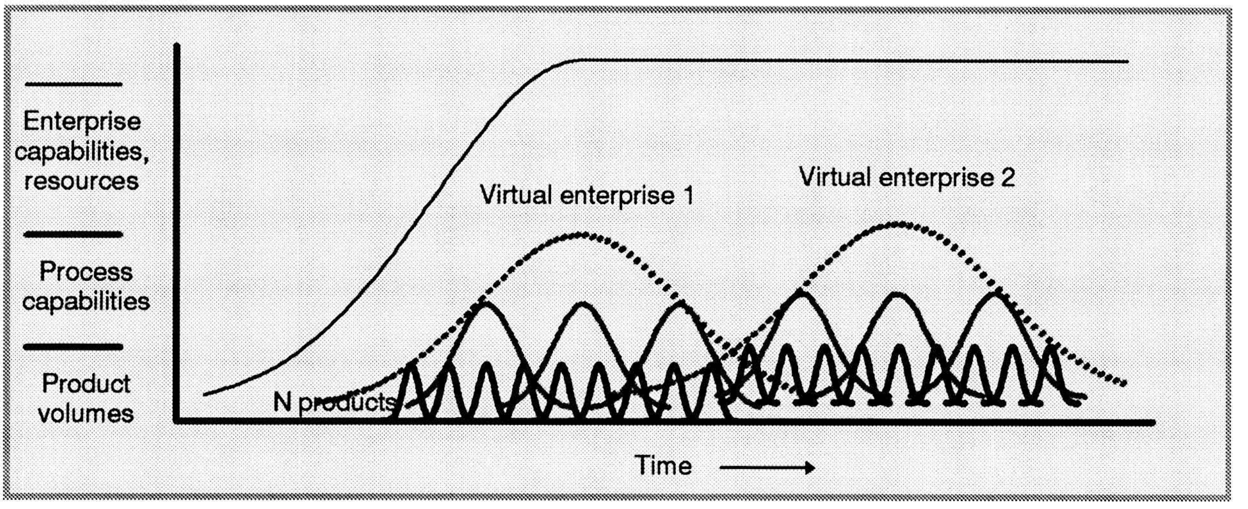


Figure 4.11: Mass-customised virtual enterprises. (Pine [52]).

According to Pine [52], the next step in business competition may very well be the Mass Customisation of enterprises, figure 4.11. These virtual enterprises are cross-functional and multi-company teams, brought together solely to accomplish a specific task. Once the market opportunity fades, the team is disbanded so that each enterprise can reapply its capabilities and resources to the next task through the next virtual enterprise. These virtual enterprises have been discussed already extensively in chapter 3.

4.7 Summary

This chapter discussed the principle of Mass Customisation. A production system combining the low costs of Mass Production, with the flexibility of Craft Production. At its core is a tremendous increase in variety and customisation *without* a corresponding increase in costs. The Mass Production of individually customised goods and services.

The Transformation Factor, shows that mass producing systems perform not at all as good as assumed in dynamic markets. Mass customising systems can be far more efficient in these dynamic markets. Where mass customisers mostly, at least presently still!, lose *some* time by changeover, mass producers appear to lose far more time by being out of spec! By considering out-of-spec products as being waste, the actual cost price, and efficiency of manufacturing systems becomes manifest.

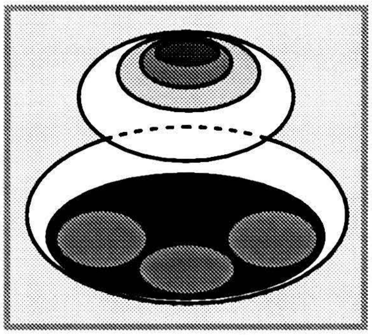
But if products are very mature, customisation can still be a great, profitable differentiator. Yet this is not the same as Mass Customisation. To demystify the different ways of customisation, four distinct approaches to customisation have been identified; Collaborative, Adaptive, Cosmetic, and Transparent.

The development of Just-in-Time, Lean Production, Time-based Competition, etc., discussed in chapter 2, has increased flexibility and responsiveness. Thus, the ability to increase variety and customisation without parallel increases in costs. Incorporated within these new ways of organising production are some basic innovations that together achieve both Mass and Customisation. The virtual organisation, virtual office, and the flexible design process, have been discussed in chapter 3. The following innovative enablers have been discussed in this chapter: modularity, Demand Activated Manufacturing Architectures (DAMA), information technology, EDI, VVC, CIM, FMS, and applying a new way of management. The latter will be discussed far more extensively in the next chapter.

In the system of Mass Customisation, a key advantage is the decoupling of product and process life cycles. The importance of individual products decreases as the same processes can be used to develop, produce, market, and deliver many products and product families.

5 Customising products and services

5.1 Introduction



This chapter will deal with the aspects concerning the demand activated manufacturing of customised products, further specified as manufacturing DAMA products. MC differs from traditional Make-to-Stock production, in that the end-user gets actually involved in the production process. The main characteristic of producing *services*. Yet producing what the consumer desires, is something what manufacturing companies are commonly not familiar with. Thus manufacturing DAMA products properly, requires excellent mass producing competencies, as well as excellent service competencies, discussed in paragraph 5.2.
To give insight in how DAMA differs from traditional Manufacturing-to-Stock, a metaphor will be used in paragraph 5.3. A pizzeria, where you can choose, entirely to everyone's own taste, from all available ingredients. Only after your desires are identified, the completely customised pizza will be manufactured. A real demand activated manufacturer thus. But, and not by accident, this DAMA example, a restaurant, is commonly looked at as a service organisation in literature.
In mass customising products, it is even more important and more complex to translate the voice of the customer into the design. The scope and range of customisation, will need to be optimised for the greatest potential of success in the marketplace without wasted effort for unnecessary customisation. A tool for systematically translating the voice of the customer into mass product designs, is the Quality Function Deployment (QFD) tool. Paragraph 5.4 will discuss this tool, and how the QFD tool can be used in designing mass customised products.
Finally, it will be discussed how organisational processes have to differ from the traditional Mass Production processes, in order to be capable of manufacturing DAMA products. Products, having characteristics of services, and of mass products. To move away from MP, some structural innovations are needed at the production organisation. The main ones will be discussed in paragraph 5.5.

5.2 Treating goods as services

The foregoing chapters showed the underlying principles of a flexible organisation. Meaning, increasing the extent to what the company is able to fulfil the fast changing desires of the consumer. According to the definition of flexibility in chapter 1, a company could be called supremely flexible, if it's able to produce and deliver exactly the kind of product each customer wants, conforming to product specifications, in the right amount, at the right time, and for the right price. The capability of delivering quality, precisely the goal of the agile mass customiser.
In 1991, Lovelock [40] stated, that relatively few consumer goods, and a majority of the industrial goods, were specially built to order at that time. The situation in the service sector, by contrast, was sharply different. Because, as Lovelock stated, there is far more scope for tailoring services to meet the needs of individual customers. Services are created as they are consumed, and the customer is often actually involved in the production process. Apparently, something what's not applied or even possible with the production of physical goods, in Lovelock's opinion. So he was definitely not having DAMA in mind.

Kotler [37] defines a service as: "A service is any act or performance that one can offer to another that is essentially intangible and does not result in the ownership of anything. Its production may or may not be tied to a physical product."
Martinson [42] as: "An economic activity that; produces an output that is not physical in nature; and produces an output that, when sold, provides utility to the customer in the form of intangible benefits.

Rosander [58] describes: "a service is a face-to-face situation in which the customer deals directly with a salesperson or clerk." When production gets demand activated, the end-user gets actually involved in the production process. Products are tailored to meet the needs of individual customers, just as with intangible services. The customised products of the DAMA organisation, further abbreviated as DAMA products, have this same characteristic as a service. Producing what the consumer desires, is something what manufacturing companies are not, but service organisations are familiar with. Thus, just having excellent mass producing capabilities, will not be enough, for manufacturing, and delivering *customised* products properly. It could (should) *also* require to have the capabilities of a top service company.

Services are not new in the industrial sector. Traditionally, three service elements are recognised in the industrial sector; direct support of the product, information and after-sales service. (Mastenbroek [44]). More and more such services are added to physical products, in order to try to meet clients' needs better. A manufacturer has to arrange the financing also for example, to get a large order. But with these Adaptive, and Cosmetic Customisation approaches, the far-reaching gains of real MC, discussed in paragraph 4.2, are not achieved. For the products produced by these customisers, are still manufactured by Manufacturing-to-Stock systems, see paragraph 4.4.
With the Collaborative Customisation approach, the customising company conducts a dialogue in determining and fulfilling customers *exact* desires, just as with services. And as discussed in paragraph 1.4, quality should also imply, the extent to what a product satisfies a customer. With DAMA, production only starts *after* determining the exact desires of the end-user. This way, quality, as defined in this report, of customised products, can be really higher than of those mass produced. Therefore, to really customise physical goods, such physical products itself will be looked at in this chapter as if it are intangible services! This way, completely new, and valuable insights will, hopefully, be retrieved in customising physical products. Besides, the production guru Jaikumar, recommended this approach already in 1986, for flexible production in dynamic markets.

> Treat manufacturing as a service; With FMS technology, even a small, specialised operation can accommodate shifts in demand. Manufacturing now responds much like a professional service industry, customising its offerings to the preferences of special market segments. (Jaikumar [32]).

The ability to talk to the customer in the Collaborative Customisation approach, is precisely the characteristic that makes these physical DAMA products 'service-like'. A restaurant is indeed looked at as a service organisation in literature. Yet, that same pizza, produced by Unilever, is typically a mass product. The interaction in customising a pizza at a restaurant, as will be discussed therefore thoroughly in the next paragraph 5.3, makes it a service.
The fact that a customer is actually involved in the production process, is the main characteristic of a service, yet not the only one. Lovelock has also stated another characteristic. Services are created as they are consumed. Just as with the consumption of a demand activated manufactured pizza. DAMA products, also meeting *this* characteristic of a service, are not just 'service-like', but could in fact be considered as really being services, despite being tangible. The distinction between products and services fades. A hungry customer enters the pizzeria, being hungry. The intangible service of the pizzeria consists of

fulfilling this need. The customer should leave NOT being hungry anymore, being satisfied properly. To this, it will among other things, be necessary to manufacture a customised pizza, a tangible product. But the customer will not make a distinction between this intangible service, and the tangible pizza.
This second characteristic allows the consumption process of the product or service to be monitored by the customising company. Valuable feedback can be received this way, as in a restaurant. It can be determined to what extent the customers' desires have been fulfilled properly by producing and delivering the customised product. If necessary, required actions can be taken right away, in trying to resolve this mismatch. This feedback can be used also in decreasing potential mismatches of future customers. By also incorporating this service characteristic in manufacturing DAMA products, customer desires will be fulfilled even better again. Being really a very flexible organisation, according to the definitions of quality and flexibility of paragraph 1.4.

As appears from the definitions of Kotler, Martinson, and Rosander, this distinction is not commonly mentioned. It's disputable how small or huge the distinctions or gains can be between 'service-like' and real service organisations. Nevertheless, it appears to be that mass customisers, demand activated manufacturers, have resemblance's to the traditional mass producer, as well as to the service company. The extent to what a company is capable of meeting fast changing customer requirements, the extent to what the company is flexible, determines the extent of urgency of the company acting like a service organisation *also*. The process characteristics of these DAMA, service-like manufacturers, differ fundamentally from those of traditional, mass producers. This will be discussed far more thoroughly in paragraph 5.3, and especially in paragraph 5.5.

So, companies having a core competency in producing and selling huge amounts of the same boxes, like many parts of Philips for instance, could face problems when offering customised ones. For this, the capabilities of a service company are required also. These companies have the experience and attitudes necessary for actually 'serving' the end-user in the right way. It is not clear which of both competencies are needed most, mass producing competencies, or service competencies. But a fact is, that some industrial markets are being entered now by specialist service companies.
Network 3 for example, is a subsidiary of the Randstad group which has addressed itself to the guarding and the security of private houses in The Netherlands. Originally this market was reserved for installation companies and manufacturers, who tried to sell their hardware directly to the public. J.E. van der Stoop, marketing manager with Network 3, established that these products did not meet customers' requirements and so left a gap in the market. "We don't sell any installations. Instead we sell security subscriptions. This means that after consulting the customer, we install sensors in the house which will set off a so-called quiet alarm if danger threatens. The alarm centre at Network 3 calls back, and informs the police if the secret customer code is not provided." (Mastenbroek [44]).

Philips is a clear example of a mass producer, unfamiliar to the offering of services. And indeed, the offering of such security products, requiring a service approach also, turned out to be incompatible with Philips' standard processes. Management was not willing to continue the execution of such deviating businesses. Thus, Philips stopped their Residential Security unit, recently.

> As a manufacturer you can no longer afford to supply only some hardware, or only software, or maintenance. You have to start thinking in terms of the concept, and offer the whole range. Thinking is going more and more along the lines of 'I need a function'. This function has to be sound, reliable and carried out as cheaply as possible. There is no point in engaging in all kinds of technical specifications prematurely, for that would be sub-optimisation. (H. Keizer, director of Philips Sales Organisation, supplying complete systems for furnishing buildings (Mastenbroek [44]).

GSM is an example of a business where the offering of a service is even far more important than the manufacturing and selling of the physical products. In the case of Network 3, the customer pays for the equipment. But, with GSM, the telephones are even given away for free. Real money appears to be made by offering services, instead of producing tangible products. The customer has to be served entirely. The whole range has to be offered as Keizer states. Not just delivering a wireless phone, but a connection, a subscription, additional services, etc. also. To be capable of serving customers entirely, requires both mass producing competencies, as well as flexible, service offering competencies.
It appears, that Philips wishes to make money by trying to serve the end-user. Yet without having all the essential competencies to do so. That appears to be at least questionable. It would be preferable to implement the DAMA capabilities to do so. To try to obtain all competencies needed for serving the end-user properly. But if not possible (yet), the next best solution is probably to look for a partner, as in the Telepost proposal. Then, Philips can focus onto the level below. The supply of parts of the desired system, like telephones and power supplies, to their partner having the capability of serving the end-user entirely. Thus in stead of serving end-users, producing large volumes of telephones for a telephone company, having the capabilities of serving that end-user properly.

Production people do not like trade. A classic example, already stated before, is the remark made by a former Ford employee about his product: "This is a fantastic truck, there simply must be a market for it!" The Ford Transcontinental was indeed a first class vehicle, but it was too heavy and too expensive for the European market. So production was stopped. This lack of understanding shows the strained relationship between production and sales, deeply embedded in all industrial companies (Mastenbroek [44]).
With services, as with DAMA, the customers get involved in the production process. These organisations act customer pull, in stead of technology push, as with the example of Ford above. Their closeness to the end-users enables them to determine exactly what clients desire. To satisfy them perfectly by fulfilling an entire function. Thinking in functions is very important in really satisfying customers. An attitude present in service organisations. Yet, a market push MP system, is not suited for such an approach as mentioned. Consequently, it is not suited for really satisfying customers. Service competencies are needed also.

5.3 The characteristics of DAMA

Thus DAMA products have resemblance's to both mass products, as well as to services. To manufacture DAMA products properly, both mass producing competencies, as well as service competencies will be needed. To understand this mix of competencies better, the differences between DAMA and traditional Manufacturing-to-Stock systems will be clarified. To this, a metaphor will be used in paragraph 5.3.1; the customising pizzeria. A pizzeria, where you can choose, entirely to everyone's own taste, from all available ingredients. Only after your desires are identified, the completely customised pizza will be made. Really a demand activated *manufacturer*. Yet, not by accident, this DAMA example, a restaurant, is commonly looked at as a *service organisation* in literature! Next, paragraph 5.3.2 will summarise the characteristics found, briefly.

5.3.1 The pizzeria metaphor

In order to describe this demand activated manufacturer properly, four different processes will be recognised in describing this pizzeria metaphor. The order taking process, the sales process, the manufacturing process, and finally the purchase process. After every discussed process, concerning notes will be made to the observed, main characteristics in customising products. Yet, this paragraph only aims at pointing out these characteristics, and to discuss them briefly. The exhaustive handling of these characteristics would go beyond the scope of this assignment.

■ The ordertaking process: The potential customer enters the pizzeria (shop). But only then, if there's one in the neighbourhood, it is easy to find, the car can be parked, etc. The location is very important. He, or she, is almost certain a customer, if the capacity of the restaurant allows. In order to maximise profits, the owner will try to get, and keep as many people as possible into the restaurant, because all are potential customers to a high degree. The capacity is chosen to be of suchlike dimensions, that given the estimated average number of potential visitors, it will optimise the overall results of the restaurant. To also keep the customers inside, an adjusted number of waitresses (clerks, shop-assistants) should be accounted for. Customers are only willing to wait for a certain amount of time.
The restaurant offers a certain range of products, pizzas in this case. Only within this envisaged scope, people can be served with customised products. For Chinese food, or French fries, people should go somewhere else.
So the customer is actually present in the company's system, and served by the waitress. The sphere and entourage, as well as a proposed drink, should make the waiting process more pleasant. Interactively, the customer and the waitress determine the exact ingredients of the pizza. If the waitress proposes a certain combination of ingredients, the customer is allowed to differentiate from this proposal entirely.
Some restaurants enable their customers to look inside their kitchen from their seats. So, people are able to watch their meals being manufactured. Another way of entertaining the waiting customer, or perhaps even astonishing the customer by the cook's (manufacturing) craftsmanship. A waiting process that, besides, should fit the expectations of the customer. A customised pizza served after only five minutes will lower the perceived quality quite. As with the Panasonic bicycles of paragraph 4.5.1.

Notes:

■ *The order taking process is exactly the one making the main difference between the two systems. The potential client, present at the service organisation, has the difficult task to determine the exact desires, interactively with the clerk. This face-to-face situation in which customers deal directly with a salesperson or clerk, is characteristic for service organisations. Quality will be determined by what these salespersons or clerks give them. These should properly determine the real, exact desires of the customers. Especially when the required judgement of the clerk in identifying the desires of the customer is high, the effects of the clerk to the user-based process quality aspect, see paragraph 1.4, will be high.*

■ *The intangible nature of services, is making marketing very difficult. It means that the services and its quality are difficult to describe to potential customers. It will also be difficult for a customer to specify exactly what he or she wants. Yet, although the DAMA products are tangible, they have the same problems as the intangible services. When buying the product or service, there is no ready tangible product available on the shelves. But generally, customers like to know in advance what they are buying, what the product features are, and what it will do for them. Surprises and uncertainty are normally not popular (Lovelock [40]). A solution can be, to use virtual prototypes. As in the example of Paris Miki, in paragraph 4.4. There, the computer system (CAD/CAM), helps the clerk in determining the right product. Finally, the customers receive a photo-quality picture of themselves with the proposed eyeglasses before actually manufacturing it. The same is done at Toyota, where a CAD system is also present at the dealership. These systems have a degree of functional realism, that is already almost comparable to that of physical prototypes, see paragraph 3.4.1.*

■ *Computer programs can be so sophisticated, user-friendly, making clerks even totally superfluous. Such programs enable customers to order customised products via, for instance, the Internet. The tangible clerk, can sometimes be exchanged by a virtual, intangible one. As uncertainty about the product outcome gets smaller, the need for a dealer gets also smaller. When ordering supplies for instance, like a printer cartridge, uncertainty of the product outcome is almost nil. But when offering relative unknown products, the necessity of dealers, capable of showing physical prototypes, is probably higher. At the intent, these systems will not, at least not yet, have the same degree of realism as the specialised CAD systems at the dealers. This, due to the commonly well-known lack of speed of the Internet.
Nevertheless, it can also be very interesting to make certain product attributes programmable. For instance, the tangible letter has been turned into e-mail. Such e-mail can be represented by the addressee in any colour, font, etc. A form of Adaptive Customisation, see paragraph 4.4. This can be applied, for instance, in spreading leaflets, by the Internet. Mass Media Customisation! The costs of distributing bits, and the reproduction, copying of it, is almost nil. Making product attributes programmable, appears to increase the ability of customisation enormous, and simultaneously decreasing the costs of customisation. Just look again at the difference in prices, and capabilities between the old type-writers, and today's wordprocessors! So, especially when producing huge amounts of the same products, like many parts of Philips, software could be an excellent tool in differentiating those mass produced products, also from those produced by rivals! Expressing the value for Philips to get more involved in software.*

■ *The customer must appear in person here, to initiate the service transaction. Also, for instance in the example of the Panasonic Bicycle company, the customer must enter a shop, to undergo a precise measurement. Their satisfaction will be influenced by the interactions they have with service personnel, the nature of the service facilities, and also, perhaps, by the characteristics of other customers using the same service. When a customer has to be physically present, the location can also be of great importance, of course.*
Dealing with a service organisation at a distance, by contrast, may mean that a customer never sees the service facilities at all. When, for instance, ordering by the Internet, the product quality remains very important, but the process of service delivery may be of little interest. Many services formerly required the customers' presence, but they are now delivered at a distance. New electronic distribution channels have made it possible to offer instantaneous delivery. Motorola, see paragraph 4.2, allows customers to phone in an (intangible) order for a customised pager. This pager will be send to the customer within 24 hours.
■ *Also characteristic is the importance of the capacity's seize, and the managing of it. The intangible services, as well as the DAMA products, can not be stored. For, they do not yet exist when the potential customer arrives. Therefore, the arrival frequencies will determine the seizing of capacity. The capacity of pubs, for instance, is completely adjusted to demand peaks at weekends. Most of the time, they are largely empty! At these weekends, more people are active than in the week, of course. Yet, a small pub, hiring extra people, is a pointless action. The capacity of the pub is the constraint! In such situations, demand fluctuations should be managed through marketing actions, according to Lovelock [40]. Especially, when the customer has to be present during the manufacturing or receiving of the service (DAMA product), as in the customising pizzeria.*
A way of smoothing the ups and downs of demand, is through strategies that encourage customers to change their plans. Such as a pizzeria, offering special discount prices during the week. Another approach, often used in services, is inventorying demand rather than supply. This by reservations, or queuing systems.
■ *Another implication that can be deduced, is the fact that the offered scope should be managed properly. Customisation can be offered only within the scope accounted for! A traditional tool for systematically translating the voice of the customer into product design specifications and resource prioritisation's, is the Quality Function Deployment (QFD) tool. Yet, in developing mass customised products, this tool will have to differ. Since the voice of the customer must be translated into families of products that define the range of customisability needed to satisfy customers. The scope and range of customisation, will need to be optimised for the greatest potential of success in the marketplace, without wasted effort for unnecessary customisation. A very important issue in customising products. Therefore, the entire next paragraph will deal with this issue.*

■ The sales process: The waitress will bring the finished pizza (product delivery). He, or she, will ask for additional wants or needs. Service, to please the consumption of the product extra. The actual sale appears to have taken place already at, or preceding of, the order taking process. And here, sales has also a planning function comprehended. When nobody is entering the restaurant, the kitchen is not being triggered. Production capacity is vacant. So actions should be taken accordingly by sales. For instance letting people have dinner for free, just to have some customers inside, to appeal other customers. The opposite is also possible. If it is very busy, it could be decided to keep part of the capacity unoccupied, in case of important customers arriving.
Finally, the customer pays its consumed product. The waitress gets direct feedback about the quality of the pizza and the service (the product).

Notes:
■ *The sales process, in a market pull, or DAMA system, differs fundamentally from sales processes in push, or Manufacturing-to-Stock systems. Here, the sales process 'feeds', or triggers the manufacturing process. Therefore, sales covers also some part of a planning function. Capacity will be sold actually. This could also imply accepting unprofitable orders, like giving pizzas away. Because fixed costs will be running anyway. As well as even refusing orders, in order to keep capacity vacant, in favour of more profitable orders possibly to arrive. In the push systems, the contents of warehouses has to be sold.*
■ *Feedback received at the sales process phase, can be very useful in re-adjusting the offered scope of products. Ingredients or modules can be removed or added. But this feedback is fundamentally different from the feedback received from, for instance Lead-Users. Lead-Users, discussed thoroughly in the report of R. de Poorter [53], give feedback in designing products for offering the proper scope. This is a long cyclic process. Yet, within a created product-architecture, and its inherent scope, feedback is also possible. After a few customers having asked for carrots on their pizzas, the offered scope could be re-adjusted, without having to design a completely new platform! Identically in the case of the Panasonic Bicycles, it could be decided to offer 1000 colour variants, instead of 199, if asked for. Contrarily, the demand for a plastic, lying bicycle, would probably ask for a completely new platform. For the current one would not account for such bicycles. But if such bicycles would really be asked for in large numbers,*

this should already have been identified much earlier, by the involvement of Lead-Users in the product creation process. These platform designs will be discussed also further on.

■ *The customer must also appear in person here, to terminate the service transaction. The implications of this, are the same as the implications of the necessity of being present at the order taking process, discussed already. But products may be delivered at home, eliminating the necessity of being present at the product delivery process. Then, the payment can take place electronically.*

■ The manufacturing process: The products of a customising pizzeria should cover the desires of all potential customers. It should not impose all customers to eat the same 'Margarita' pizza of course. The bottom of the pizza (part of a platform design), anticipates to this. For the bottom, within its limits, allows for putting all kinds, and amounts of ingredients onto the pizza. This way, the possible scope to be offered has been attained, and set also.

As the pizza has been ordered by the customer, the pizzeria should be capable of producing that pizza within about half an hour. Therefore, the completion of such a platform (an architecture), should be such that this is possible (it should be DAMA-enabling). To this, the pizza has a modular architecture, as discussed in paragraph 4.5.1. Moreover, the pizza architecture is very open. For instance cheese of any supplier can be put onto the pizza. Making it easier to attain the required ingredients (modules). And allowing to attain not only economies of scope, but also economies of scale with ingredients.

All ingredients, possibly needed, are already present (stocks of components). With, for instance twenty ingredients (components, modules), a virtual infinite diversity of pizzas can be offered (economies of scope can be achieved). The dough (a half-fabricate), has already been made previously, based on a predicted number of clients that evening. Yet, if far more customers arrive than expected, extra dough can be made timely. Having in mind that the total of customers can never exceed the capacity accounted for. This also applies for the stocked ingredients.

The pizza will be manufactured specifically for the concerning consumer, provided with the requested ingredients. The capacity of the kitchen, should also be adjusted to the capacity of the restaurant, and the amount of waitresses, of course. Because if crowding is at a maximum, waiting times should still not exceed tolerated levels. Production can be extended to larger scales by extending the size of the restaurant, but also by allowing pizzas to be taken away.

Notes:

■ *The design of a DAMA product should cover the desires of all potential customers. To this, the function of the product should be defined first, see also paragraph 5.2. But as discussed, in developing mass customised products, the voice of the customer must be translated into families of products that define the range of customisability needed to satisfy all customers. So from the function, in a so called platform design, ranges of specifications should be derived and set, instead of absolute values as commonly with mass produced products, see also paragraph 5.4. Furthermore, the customer ordering a DAMA product, is only willing to wait for that product for a certain amount of time. It should be possible to manufacture the product ordered within this period! Thus, the product architecture should be 'DAMA-enabling', for instance, by means of modularity, discussed extensively in paragraph 4.5.1. Open architectures are also DAMA-enablers. As an architecture is more open, more companies will be able to supply modules, making it easier for the mass customiser to attain the required modules.*

A platform design allows to, not only attain economies of scale, but also to attain economies of scope, and the application of commonality. The latter, in order to keep diversity of components manageable. For instance, a power supply unit would traditionally appear in numerous variants. Yet, by having just one type of power supply, provided with switches to adjust the desired voltage, the diversity of components will be sharply reduced. This way, the offered scope remains the same, yet reducing the efforts in managing this variety, and its associating costs, enormously. Also, design will only have to account for one type of power supply.

■ *Capacity has been overstated, as in all service organisations, in order to be capable of managing demand fluctuations properly. These can be managed also by applying the traditional waiting time theories, like reservations for instance. This has already been discussed at the order taking process.*

■ *The ingredients are supplied, thus produced centrally. But the final customisation, 'bundling', takes place at the dealer. So the location of production systems will have to be re-considered in customising products. This has to be recognised, and reckoned with already in the design phase. Thus not only what parts of the products will have to be customised, the managing of the scope. Yet, also where each of these have to be customised. The to Mass*

Customisation adjusted QFD tool, to be discussed in paragraph 5.4, does account for this. It identifies where and by whom the customisation will be done.

■ The purchase process: All possible ingredients asked for, will be purchased, based on predictions and experience. These have to be fresh, so that the purchasing frequency should be very high. Daily, or two times a day. This way, there will never be much stock. The logistic processes should therefore be very fast and flexible. The suppliers should be prepared to this. These can be huge mass producers, achieving economies of scale on these ingredients (components, modules), as with the enormous greenhouses for instance. By using these supplied ingredients, the quality of the pizza is effected largely by the quality of these ingredients supplied.
The prediction of end-products demand, is based on the expected number of customers that evening. Partly predictable, partly not. As stated already, the owner knows that the total of customers can never exceed the capacity accounted for. And knows also, from experience, for example that fewer meat is consumed at Fridays. Yet, they will never know the exact number of customers. But the purchasing process is very flexible in adapting to fluctuations, trends, or opportunities. If cow-meat is not wanted anymore, the restaurant can in stead order chicken-meat immediately. Therefore having the ability to offer chicken-meat as an ingredient already next day! And, also not having to throw away much cow-meat. Stocks of pizzas (finished products), are not present, of course. These stocks shift to stocks of ingredients, where dynamics, and variety of demand is much less.

Notes:
■ *Economies of scale will be attained at the component, or module level. Manufacturing of components, or modules, will remain by more traditional systems, at usual locations. These components are stocked, limited, and can be re-ordered very flexible.*
■ *Buying for price is considered to be less expensive, formerly. Yet in highly dynamic markets, buying for price will not always result into the lowest costs. The purchasing process should also already focus on realising the desired overall quality, necessary in fulfilling the customer's desires properly. See also paragraph 1.4, for the definition of overall quality. Incorporating flexibility, the capability of delivering quality, can be less costly, as discussed in paragraph 4.2, although actually calculating the real integral costs appears to be unfeasible. Therefore, the rule of thumb should be: In dynamic markets, always buy for quality, if affordable, when there's no evidence that buying for price will really result into lower overall costs.*

5.3.2 Summary of findings

The metaphor of the pizzeria, has resulted into a number of findings, with regard to (the quality of) the customisation of products. There's a striking resemblance between services, and DAMA products. The main findings noted, are summarised in table 5.1. Findings, thus deduced from a service approach, yet applied to attain insights in customising DAMA products properly.

Table 5.1: Summary of the pizzeria metaphor findings.

	Summary of the main findings of mass customising products
1.	Quality is determined in interaction with the end-user at the dealer.
2.	Uncertainty of the final product outcome, because of the absence of the tangible product, with virtuality as a possible solution (partly).
3.	Challenge; making product attributes programmable (partly), making modularity also less essential.
4.	Presence necessity of the customer in initiating, and terminating the customisation process, with Internet as a potential solution in some cases.
5.	Managing demand fluctuations, through marketing actions, and by applying traditional waiting theories. Necessity of having over-capacity.

6.	Changed function of the sales process, selling capacity.
7.	Feedback at sales in re-adjusting the offered scope of existing architectures. Feedback of Lead-Users in designing the right platforms.
8.	An adjusted QFD tool, for defining ranges of specifications for a platform design.
9.	Applying platform designs for attaining economies of scale and scope simultaneously, as well as commonality for keeping the diversity manageable.
10.	Product architectures should be 'DAMA-enabling', for instance by means of modularity, and open architectures.
11.	In dynamic markets, buy for quality, if affordable, whenever there's no evidence that buying for price will *really* result into lower overall costs.
12.	Re-consideration of the location of various manufacturing, customisation steps.
13.	Economies of scale is (still) attained at the component, module level.
14.	Limited presence of components, modules stocks. Absence of finished products stocks.

5.4 Designing mass customised products

In developing a qualitatively good product, according to the definition of quality in chapter 1, it is essential that products are designed to reflect customers' desires and tastes. A tool for systematically translating the voice of the customer into product design specifications and resource prioritisation's, is the Quality Function Deployment (QFD) tool. Its strength is to translate subjective customer wants and needs into objective specifications that engineers can use to design products (Anderson & Pine). It has been mentioned, that in finding these customer wants and needs, the Lead-User method can be of great help. Yet, this will not be dealt with here, for this has already been discussed extensively in the report of R. de Poorter [53].

Paragraph 5.4.1 will discuss the QFD tool generally. Yet, this tool will have to differ in developing mass customised products, as mentioned. Because for MC it is even more important and more complex to translate this voice of the customer into the design. Since the voice of the customer must be translated into families of products that define the range of customisability needed to satisfy customers. The scope and range of customisation, will need to be optimised for the greatest potential of success in the marketplace without wasted effort for unnecessary customisation. Therefore, paragraph 5.4.2 will discuss how the QFD tool has to differ in accomplishing this.

5.4.1 The Quality Function Deployment tool

QFD was developed to help designers find the links between customer needs and design elements. The purpose of QFD is to translate customers' vague statements into actionable design specifications. It also provides an objective, structured forum in which people from various functions in the organisation can discuss their needs and opinions on the design (Rust, a.o [59]). This way, marketing people, design engineers, and manufacturing staff are forced to work closely together from the time a product is first conceived.
The central tool of QFD is a diagram called the House of Quality. Figure 5.1 shows such a QFD chart with each area labelled according to its function in the methodology. For a better understanding, it depicts an example of a car door.

The House of Quality starts with a set of subjective customer requirements, the input to QFD. Phrases customers use to describe products and product characteristics, and generally produced in the customers' own words. A car door is for example "easy to close", or "stays open on a hill". But not all of these customers are end-users. ***Customer requirements***, often called ***customer attributes*** in QFD, can also include the demands of regulators ("safe in a side collision"), the needs of retailers ("easy to display"), the requirements of vendors ("satisfy assembly and service organisations"), etc. Next, these customers are asked for the ***relative importance*** of these attributes. These ***weightings*** are displayed in the house next to each customer attribute, usually in terms of percentages, a complete list totalling 100%.

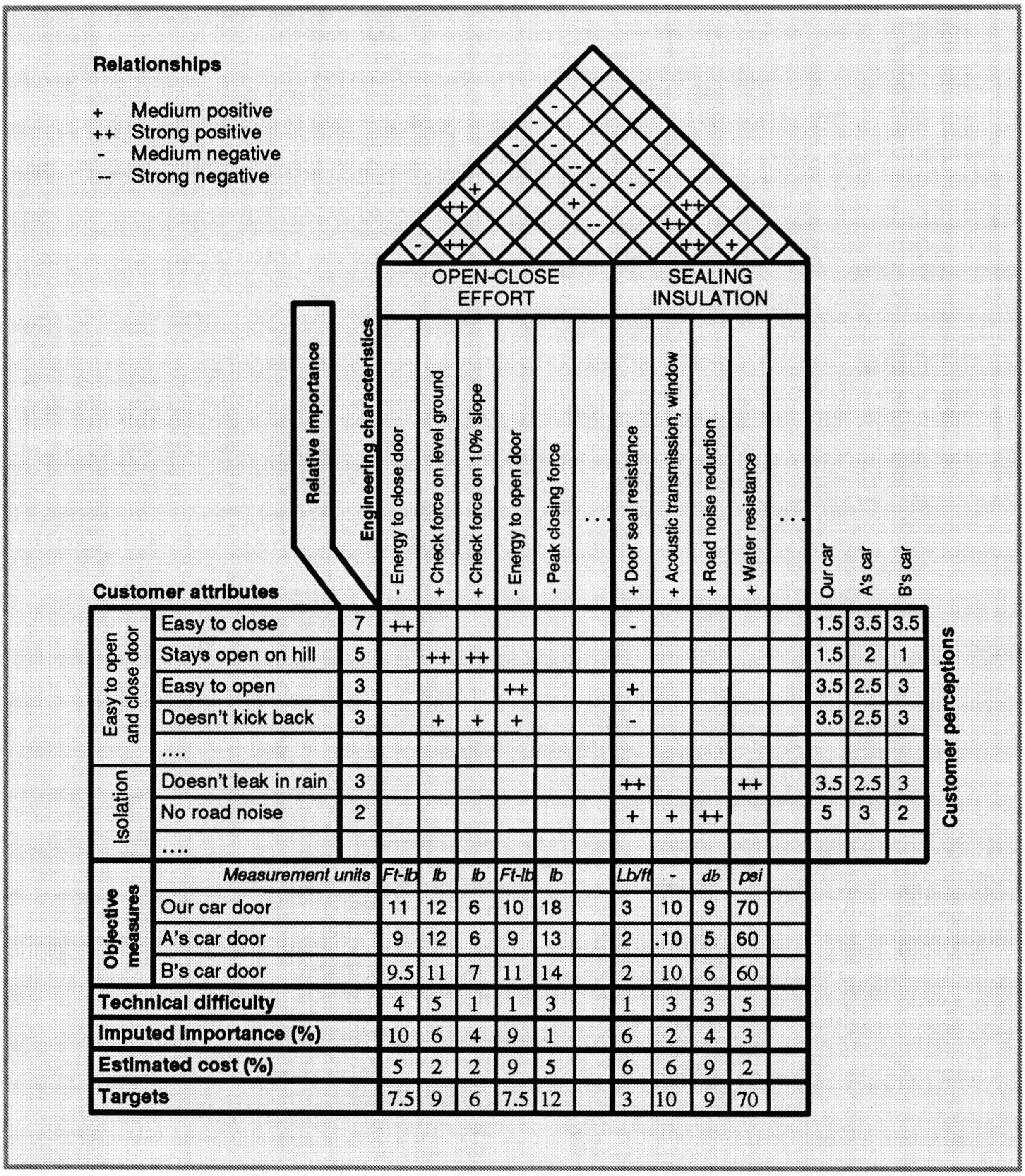


Figure 5.1: The House of Quality for a mass produced product. (Clausing [11]).

Companies that want to match or exceed their competition must first know where they stand relative to it. Therefore, on the right side of the house, the ***customer perceptions*** of competitive products matched to 'the own' are listed. The collection of such customer perceptions is also known as a ***perceptual map***.
The marketing domain tells what to do, the engineering domain how to do it. To this, along the top of the house the product is described in the language of the engineer, the ***objective engineering specification measures***, or ***engineering characteristics***. These are likely to affect one or more of the customer attributes. For example the resistance of the door seal, affects three of the four customer attributes shown in figure 5.1. The negative sign on "energy to close door" means engineers hope to reduce the energy required.
The body of the house, the ***relationship matrix***, or ***correlation matrix***, indicates how much each engineering characteristic affects each customer attribute. Numbers or symbols are used to establish the strength of these relationships. Once the identified voice of the customer is linked to engineering characteristics, ***objective measures***, or ***measured specifications***, are added at the bottom of the house. Quantified dimensions, forces, torque's, energies, decibels, etc., beneath the engineering characteristics to which they belong. The ***resource prioritisation***, or ***imputed importance***, can be given in a percentage of the engineering budget or hours spent achieving the various design targets. Here, also a row indicating the degree of ***technical difficulty***, is added. It shows how hard or easy it is to make a change. And also a row showing the ***relative costs***. Finally, the ***target values***, or ***design specifications***, can be established. Ideal new measures for each engineering characteristic in a redesigned product.
The ***roof matrix***, the ***conflict matrix***, helps engineers specify the various engineering features that have to be improved collateral. It gives any specifications that might be inherently in conflict with each other. It helps in making trade-offs of one feature versus another. Changing the gear ratio on a car window may make the window motor smaller but the window go up more slowly. And enlarging or strengthening the mechanism, will make the door probably heavier, harder to open, or will less easy remain open on a slope (Clausing & Hauser [12] / Anderson & Pine [02]).

5.4.2 Quality Function Deployment for Mass Customisation

For MC, all products in the customisation family must be defined so that customers can actually receive custom products. Therefore, the definition of the product is not a single definition, but is a range of product definitions that represent various combinations of modules, standard parts, custom parts, custom configurations, and customised dimensions. As stated before, this way a platform design is obtained.
To design products and processes for MC, the scope of products to be offered must be understood. As discussed, it is important to establish the optimal scope of products. It may not be necessary or even feasible to offer every possible variation of products in a product family. Customers may need only certain variations, as indicated by their inputs on relative importance. Therefore, it would be a waste of effort to offer more variation than is really appreciated. So mass customised products must be defined with the optimal scope of customisation (Anderson & Pine [02]).

So, MC needs a methodology for translating the voice of the customer for families of customised products. Figure 5.2 shows the QFD chart for MC. The target values, or design specifications has been expanded into five rows. The first new row, ***to be customised by***, indicates if the product is customised in the factory (F), at the dealer or distributor (D), at the point of sale by the user (P), by the user's technical staff (T), by the actual end-user (U), or self-adjusting (S).
The purpose of these entries is to identify where and by whom the customisation will be done. The design team will have to design the product for compatibility with this customisation strategy. Factory customisation would rely on FMSs, to be able to quickly build any configuration that is called for. Dealer, distributor customisation would have to consider the tools, parts, patience, and skill level present at all dealers and distributors. User customisation would have to be designed for the anticipated range of users'

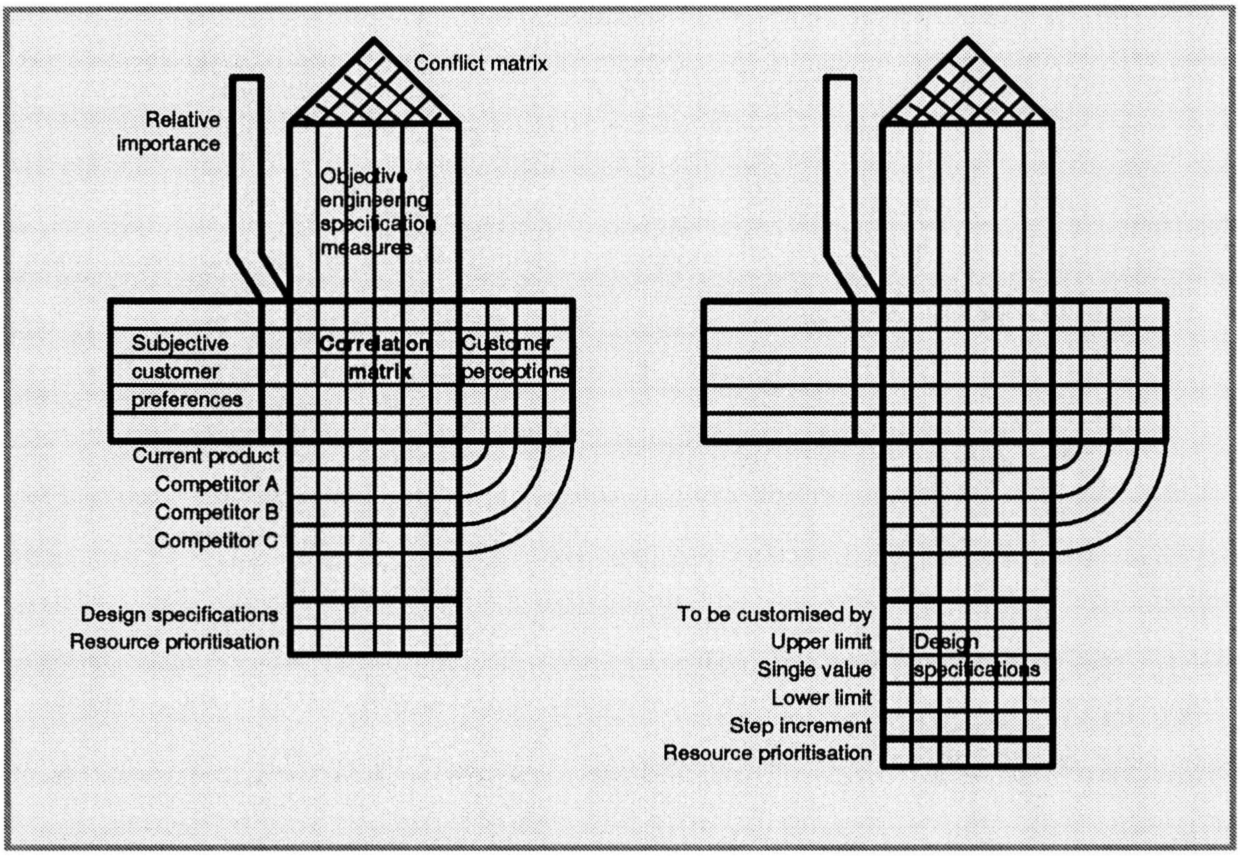


Figure 5.2: The House of Quality for a mass customised product. (Anderson & Pine [02]).

skill level, patience, and tools needed, if any. User customisation would be a situation common in large companies where technical staffs or departments would perform the customisation, for instance configuring computers for all office workers. Self-customising products literally adjust automatically to fit the user, called Adaptive Customisation in paragraph 4.4.
The next three rows contain ***upper*** and ***lower limits***, specifying the range of dimensions for engineering characteristics. And the ***single value***, which would be used for those engineering specifications that can be expressed by a single value and not by a range of values. The step increment would specify the steps or increments that could be appropriate for values within the range. A zero entry would indicate infinitely variable dimensions between the upper and lower limits (Anderson & Pine [02]).

5.5 Process aspects DAMA products

The previous paragraphs discussed the problems, and points of attention in mass customising products properly. But, how do organisations have to differ from traditional mass producing organisations, in order to be capable of mass producing such 'service-like', customised products. Pine [52] mentions the new organisational processes required to mass customise products and services. Gunneson [24] discusses the differences between the mass producer, and the agile company. Other authors, Goldhar & Schlie [23] for example, also describe main characteristics of the flexible organisation. All bring in different processes, aspects, or name apparently equal processes differently. Yet, by comparing them, a number of processes appear to be most important, generally. Table 5.2 embraces these main differences between the inflexible MP system, and the flexible, MC systems.

Table 5.2: Comparing mass producing organisations to mass customisers.

Mass producer	Process characteristics	Mass customiser
Compartmentalisation		Decompartmentalisation, time acceleration
Technology focus		Market focus, customer orientation
Vertical organisation structure /		Networked, virtual organisation structure /
Aggregation of the value chain		Disaggregation into business cells
Supplier certification		Suppliers are virtual partners
Hierarchy of approvals , working alone		Empowerment, working in teams
Job skills required		Multi-dimensional business skills required

The characteristics of the flexible mass customiser, mentioned in table 5.2 above, will be discussed next:

■ **Compartmentalisation ⇔ Decompartmentalisation, time acceleration:**

Current processes should first be analysed to determine who the customers are, what inputs are provided, what value-adding occurs, and what the outputs are. The value chain of the company should be examined in a horizontal, logical, customer-focused manner. Organisational structure can be so compartmentalised that people rarely talk to those in other areas. Even when servicing the final customer demands. Redesigning processes can break down the vertical compartments and organisational barriers. Every boundary provides an opportunity for miss-communication, and all manners of quality defects. All at the expense of satisfying the wants and needs of the final customer. As well as the wants and needs of the next customer in the chain of customers leading to that final one. The one that pays everybody else's expenses.

If processes neither add value to the final customer nor help the chain of internal customers add value to the final customer, those processes should be eliminated see also paragraph 2.2.1, and paragraph 2.3. It will then be possible to drastically reduce cycle times, by speeding up processes, see also paragraph 2.4. According to Pine [52], Time-based Competition is an excellent way to turn into a mass customiser. To the latter, the set-up time should finally be drastically reduced or eliminated. All of this will allow a company to reduce the process lot size to one, to become a mass customiser.

> The United Services Automobile Association (USAA), has done all of this. It provides insurance's for military and ex-military personnel. It eliminated its paper inventory, eliminated waste in the process, and brought its cycle time down to its value-added time. Now it works in lot sizes of *one* customer who gets personalised service. (Pine [52]).

■ **Technology focus ⇔ Market focus, customer orientation:**

Most firms that believe in the paradigm of MP focus much more on the products they have to make and sell than on their customers. They produce for inventory, and that inventory has to be sold. Recently, many of the best of these companies have changed their focus from products to markets. Becoming market-driven is an excellent first step away from MP (Pine [52]).

In the system of MC, the customer will trigger production. Products will be manufactured specifically to the needs of that customer. To this, the longer cyclic processes of the company are also customer focused. Customers, and suppliers also, are for example also participating members of product and service design teams (Gunneson [24]).

■ Vertical organisation structure / aggregation of the value chain ⇔ Networked, virtual organisation structure / disaggregation into business cells:

The traditional vertical organisation structure, was designed to exploit economies of scale to a maximum extent. Its command and control structure and vertical communications were suited to relatively stable and controllable environments. It is particularly unsuited to turbulent environments that demand fleetness, agility, and responsiveness. The networked or virtual organisation is designed to exploit economies of scope to a maximum extent, as well as economies of scale, in dynamic environments. The current innovative enablers, discussed in paragraph 4.2, allow these flexible companies to not only score off mass producers towards economies of scope, but as well as towards economies of scale!

The purpose of decentralisation is to push decision-making authority down in the organisation. Closer to where the action is and to where the people are who have the knowledge to apply to the decision. Greater flexibility and responsiveness arise from not having to gain approvals up and down the organisational hierarchy [52].

> If an individual is closer to his work, is more responsible for what happens as a result of his or her actions, that person is likely to do a good job. And if a good job isn't done, then failure is right there, with no place to hide from it. (Vasilash [52).

> We have passed the Taylor stage. We are aware that business has become terribly complex. Survival is very uncertain in an environment filled with risk, the unexpected, and competition.... We know that the intelligence of a few technocrats, even very bright ones, has become totally inadequate to face these challenges. Only the intellects of all employees can permit a company to live with the ups and downs and the requirements of the new environment. Yes, we will win and you will lose. For you are not able to rid your minds of the obsolete Taylorisms that we never had. (Konosuke Matsushita [08]).

But all to often people are uncomfortable with new found autonomy and the responsibility that goes with it. If they can still pass the buck back upstairs, they will. Top managers are often reluctant to give up their power, despite claiming the contrary. Not only separating the organisation into decentralised units, but also turning the units into its own company, can be a solution. It sets everyone's focus on the task at hand, while eliminating all excuses and temptations to revert back to the old ways of doing things (Pine [52]).

> **ABB (Asea Brown Boveri) is the largest electrical systems and equipment company in the world. But the work of most of their people is organised in small units with P&L responsibility and meaningful autonomy. Their operations are divided into nearly *1200* companies with an average of *200* employees. These companies are divided into 4500 profit centres with an average of 50 employees. Yet it runs its Zurich headquarters with only *one hundred* people. (Pine [52]).**

Many companies are outsourcing various functions and activities: cafeteria management, building maintenance, information systems development, transportation logistics, and even, product design, secretarial support, manufacturing, sales, etc. Companies are outsourcing because they can get better service, at lower costs, from other companies that specialise in one activity, do it well, and learn by doing it for many others. So why not turn your specialised functions into their own companies (Pine [52]). If internal processes can't cut it in open competition, the former organisation deserved better. Now, these competitive, core processes are forced to go after new business while allowing their former internal customers to choose among suppliers. This way the old organisation turns into a (temporary) virtual, collaboration of autonomous processes (now called companies), owned by different parent companies. These virtual organisations have been discussed extensively in chapter 3.

Japanese suppliers and contractors are not exclusively tied to a single customer. Many supply more than one customer. This provides the supplier greater security and stability. . . **Nippondenso**, an electrical company. . . is still 23 percent owned by Toyota, but now does 40 percent of its business with other firms, and it supplies parts to some of Toyota's competitors such as Honda, Ford, and General Motors. (Florida & Kenney [17]).

Along with many other Japanese firms, Kuniyasu Sakai, cofounder and former chairman of Taiyo Kogyo K.K., practices the philosophy of '*bunsha*' or 'company division'. Sakai has constantly divided his company into smaller ones over the past forty years (Pine [52]).

I believe you can go into any traditionally centralised corporation and cut its headquarters staff by 90% in one year. You spin off 30% of the staff into free-standing service centres that perform real work - treasury functions, legal services - and charge for it. You decentralise 30% of the staff - human resources, for example - by pushing them into the line organisation. Then 30% disappears through head count reductions. (Percy Barnevik, ABB's president and CEO [52]).

■ **Supplier certification ⇔ Suppliers are virtual partners:**
The mature mass producer has a supplier certification and rating system in use. But only selecting the best supplier, will not be enough. Suppliers should become virtual partners. Participating in for example product design (Gunneson [24]). Working together as a partnership, you can increase quality, enhance flexibility, reduce cycle time, lower costs and provide innovations (Pine [52]). IKEA, for example, plays a major role in improving the business infrastructure and manufacturing standards of its partners.

IKEA employs about a dozen technicians in a unit called IKEA Engineering to provide suppliers with technical assistance. The company's Business Service Department runs a computer database that helps suppliers find raw materials and introduces them to new business partners. So the suppliers are also customers, of IKEA's business and technical services. (Normann & Ramirez [47]).

Toyota had demanded reductions of costs of one of their supplier plants. The supplier attempted to do so, but failed to see how cost reductions could be achieved without damaging its own business position. When the supplier reported this failure to Toyota, the Japanese response was to send their own engineers to the supplier plant. In under *three months* costs had been reduced by *20 percent* without hurting their own business. Toyota benefited but so did the supplier. (Brown [09]).

■ **Hierarchy of approvals, working alone ⇔ Empowerment, working in teams:**
Top management can instigate and even institute each of the structural changes discussed so far. But it is the employee of a firm who must make the real changes, and who has the knowledge to do so. Getting out of the way and letting him do it is empowerment. Many employees may be out of practice or reticent to speak out, because of the traditional separation of thinking and doing. So working beyond that will require time, patience and trial and error (Pine [52]).

> We will win and you will lose. You cannot do anything about it because your failure is an internal disease. Your companies are based on Taylor's principles. Worse, your heads are Taylorised too. You firmly believe that sound management means executives on the one side and workers on the other, on the one side men who think and on the other side men who can only work. For you, management is the art of smoothly transferring the executives' idea to the workers' hands. (Konosuke Matsushita [08]).

Creating and empowering cross-functional teams that can quickly bring together the diverse skills, knowledge, and experiences. Those teams should be focused on a particular horizontal task, a project focus, not a functional perspective. And they should be given the power, authority, and tools to accomplish it. Self-directed teams can effectively destroy the functional and organisational boundaries built up over the years (Pine [52]).

■ **Job skills required ⇔ Multi-dimensional business skills:**
A consequence of the separation of thinking and doing is the belief that excess knowledge is inefficient. Workers need to know only how to do the task they are assigned and nothing else. People at mass producing organisations, functional organisations, need only to know about their function. It is clear that in today's environment this attitude will no longer work. When uncertainty and instability are the rule, and flexibility and responsiveness essential requirements, then excess and redundant knowledge becomes crucial to survival. Workers should become multi-skilled, higher educated, in order to be capable of dealing with their increased responsibility, and accountability properly.
The move to cross-functional, self-directed teams is a way companies have been applying excess knowledge in parallel to formerly serial, one-function-at-a-time tasks. Innovative companies like Bally Engineered Structures are creating databases of their people's skills and experiences that can be accessed across the company, allowing anyone to instantly find the person with the right knowledge to apply to a new situation. And the Internet can of course be of great help in generating excess knowledge (Pine [52]).

Paragraph 4.3 discussed that MC systems will outperform MP systems in dynamic markets. To understand this, it is essential to consider quality as defined in chapter 1. It makes clear, that out-of-spec products are actually waste. In calculating cost prices, technical waste, as well as these out-of-spec products should be taken along, see formula 4.6. Defining quality, and costs like this, is something every mass producer should do. This way, it will turn out that in dynamic markets, incorporating the flexible processes discussed, is actually less costly than having the inflexible processes of MP. In dynamic markets, inflexible processes result into products having the wrong specifications. In products being waste. For instance:

- Focusing on technology, neglects accounting for market dynamics in the early design already.
- Compartmentalisation does not allow responding to fast changing customer desires timely.
- Hierarchies of approvals result into severe time delays, leading to missing the market window.
- Supplier certifications do not guarantee supplied components to meet the by the end-user desired perceived quality.

Applying these definitions will shift mass producers in dynamic markets in the direction of mass customisers. And, ultimately becoming one. Even when not intending to become a mass customiser at all! For flexible processes decrease costs. Companies like Toyota and Matsushita for instance, are definitely not aiming at becoming a mass customiser, chasing some higher goal. No, by defining costs, and quality different as traditionally in mass producing environments, they obtain the mass customising processes of table 5.2. They turn into mass customisers almost 'automatically'.

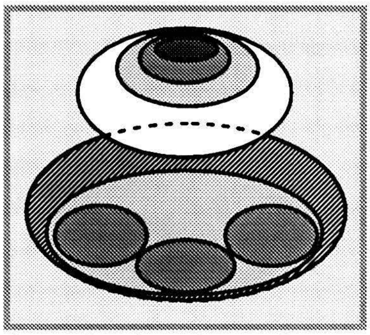
5.6 Summary

Services are tailored to meet the needs of individual customers. The customer is often even actually involved in the production process. But DAMA products have this same characteristic as a service. Precisely the one that differentiates the manufacturers of these customised goods, chiefly, from their mass producing colleagues. This ability to talk to the customer in the Collaborative Customisation approach, is precisely the characteristic that makes physical DAMA products 'service-like'. By fulfilling customers *exact* desires, quality, as defined in this report, of customised products, can be really higher than of those mass produced.
Also characteristic for services is, that they are created as they are consumed. DAMA products, also meeting *this* characteristic of a service, are not just 'service-like', but could in fact be considered as really being services, despite being tangible. It allows receiving valuable feedback, by monitoring the consumption process. By also incorporating this service characteristic in manufacturing DAMA products, customer desires will be fulfilled even better again.
Thus DAMA products have resemblance's to both mass products, as well as to services. To manufacture DAMA products properly, both mass producing competencies, as well as service competencies will be needed. To understand this mix of competencies better, a metaphor, the customising pizzeria, has been used. It tried to clarify the differences between DAMA and traditional Manufacturing-to-Stock systems. The metaphor resulted into a number of findings, summarised in table 5.1, with regard to (the quality of) the Mass Customisation of products. Findings, deduced from a service approach, yet applied to attain insights in customising 'service-like' DAMA products properly.

When mass customising products, it is even more important and more complex to translate the voice of the customer into the design. Since the voice of the customer must be translated into families of products that define the range of customisability needed to satisfy customers. The scope and range of customisation, will need to be optimised for the greatest potential of success in the marketplace without wasted effort for unnecessary customisation. It has been discussed how the conventional Quality Function Deployment tool has to differ in accomplishing this.
The problems and points of attention in mass customising products properly have been discussed. But organisations have to differ from traditional mass producing organisations, in order to be capable of mass producing such 'service-like', customised products. To move away from MP, some structural innovations are needed at the production organisation. A move that will take place almost 'automatically', if the definitions of quality and costs, as discussed in paragraph 4.3, are applied. For it will turn out, that flexible processes are actually less costly in dynamic markets, than the inflexible processes of MP. Table 5.2 embraces these main differences between the inflexible MP systems, and the flexible, MC systems.

6 Demand activated manufacturing in practice

6.1 Introduction



The preceding chapter 5, discussed the points of attention in mass customising products. Characteristics of those products were derived by comparing products to services, like pizzas. It was also discussed, how DAMA processes should differ from the processes of traditional mass producing companies. After having explicated these characteristics and processes, it would be recommendable to check these in practice. A difficult task, for mass customising companies are not often willing to exhibit their entire organisational structure, and processes, the source of their competitive advantages. Nevertheless, an entrance has been found at Tulip in s'-Hertogenbosch, after all. Paragraph 6.2 describes this flexible demand activated manufacturer. This real case example will indicate the practical value of the findings of chapter 5. After having looked at this real mass customiser, a fairly good image of the flexible organisation should have been obtained by then.

On July 25, 1996 the Board of Management of Philips revealed that developments in the industry and the markets of Consumer Electronics required a structural realignment of the Philips Sound & Vision activities. They, also, realised, that a fundamental change of the ways of working in the total business chain from supplier to customer was needed. Therefore, the FIL supply chain management project was raised. It should bring Philips Sound & Vision to World Class Performance. Paragraph 6.3 will discuss to what extent this project is aiming at achieving flexibility, and how Philips expects to realise their goals. Next in this paragraph, the obtained image of the flexible organisation will be compared to the goals of this project, and to the attempts of Philips in realising these goals. It will be discussed that, and how Philips should incorporate DAMA, in order to really achieve World Class Performance.

Only practical experience will show the real value of the findings of chapter 5, in mass customising products by Philips. It's recommendable to start practising DAMA as fast as possible, in order to put Philips on the learning curve. But start implementing DAMA at the FIL entities to be discussed, is a very complex issue. In order to get onto the learning curve already now, Philips could start less complex DAMA projects, in partnership with a third party service company. Precisely for this, paragraph 6.4 will discuss another practical, and successful, DAMA example. The Telepost services of the Dutch PTT. This service allows you to send the Dutch PTT messages, congratulations, electronically, which are then printed, folded, inserted, affixed postage, and send via conventional snail mail. The theories discussed in this report will be released to this PTT case, in accomplishing an actual, new DAMA proposal. This by extending the Telepost services currently offered by PTT Post.

6.2 Demand activated manufacturing at Tulip

This paragraph will discuss a real DAMA example, in order to be capable of checking the expressed theories of chapter 5 in practice. To this, Tulip, a computer manufacturer in s'-Hertogenbosch, has been visited. It is one of few accessible practisers of the principle of DAMA. Because of its nearness to Eindhoven, and the already existing contacts with the University of Technology at Eindhoven, it was, at least after insisting, possible to get a look inside this completely renewed, advanced company. A company, like Philips, active in a very dynamic market of electronic products. And also like Philips, a company having enormous problems in coping with these dynamics. Yet, because of the even greater dynamics of the computer business, Tulip has been forced to make the essential renewal already. Because of the resemblance's, the attained insights could be very useful, and valuable for comparing these to Philips in paragraph 6.3. Paragraph 6.2.1 summarises the findings obtained by an interview held with M. van de Ven, currently a project-leader, and formerly a business process re-engineer, of Tulip. Next in paragraph 6.2.2, Tulip will be compared to the insights attained in chapter 5.

6.2.1 Tulip

At the end of 1996, Tulip opened its completely renewed plant and offices, for the manufacturing of computers. Formerly, these computers were Manufactured-to-Stock. But this MP system has been replaced by a Build-to-Order system, where manufacturing is started only after an order is received. It enables Tulip to produce and deliver customised products, varying from just one system to for instance 5000 systems, and on the average 5. All business-to-business, end-users are not served. These orders are delivered by the factory within 48 hours, and are then transported to the customers. At the end of this year, production will be planned twice a day instead of once, halving delivery times to only 24 hours.
For orders consisting of less then 100 systems, the customer has to choose from a fixed range of modules. Yet, this range is already resulting into an almost infinite diversity. For larger orders, everything technically possible can be delivered. But seldom the requests fall outside this fixed scope.
30% of the capacity is currently reserved for rush orders, delivery next day. By spreading orders in time, possible because most business-to-business clients prefer delivery reliability over fast delivery, the resulting 70% can be utilised more effectively. If demand fluctuations exceed normal, so called flexpoolers can be called up within 24 hours. Workers, trained and educated by Tulip itself.
90% of Tulip's turnover is achieved by only 60 combinations. The resulting 10% comprises an almost infinite diversity of systems. In the current flexible system available as fast as the standard 90%. Formerly, only the standard systems could be delivered (from stock).

Tulip produces its boards itself. In their factory in England, the bare boards, 8 different types, are manufactured. The components are placed on these bare boards in 's-Hertogenbosch, including video, sound, and IO. One such board contains about 500 to 1000 components. After this placement, the finished boards are tested automatically. The yield of this process is 98%, after a preliminary stage. The resulting 2% will be repaired. Therefore, the overall yield totals 100%. The finished, and tested boards are stocked, thus not produced to order. Only when orders are very huge (thousands), components are placed at the boards to order, if wanted. The components needed, are being purchased, and stocked also. To keep these stocks to a minimum, the sales department hands over a sales forecast monthly, six months ahead, with the first month specified into weeks. They receive feedback of the actual sales.

The cabinets are being designed by Tulip itself, yet produced by a third party. These are also being stocked, just like the other modules purchased. Only the final products are not being stocked. For these are only produced when ordered. In the former build-to-stock system, the average stocks totalled Dfl. 120 million. Now, in the current system it totals only Dfl. 45 million. This due to the elimination of stocks of end-products, and due to reduced stocks of components and modules. The latter by the drastically improved forecasts, and its feedback of actual sales, resulting into a much better planning and purchasing process.

The production system has been changed drastically. Formerly, the computers were produced according to the line principle. A worker accounted for only one specific assembly step. After the assembly of a

specific module, the half-product went on to the next worker, for the next assembly step. A worker carried out the same assembly step all day. At his/her place on the line, huge amounts of modules to be assembled were stocked. The output of this system was determined by the slowest link in the chain.
Now, Tulip has changed to cell production. In the storage room, all modules to be assembled into one system, will be picked first. This order picking has been automated partly now. A product carrier, containing all modules after picking, has been provided with an escort memory chip. At the different pick locations, this chip, containing the exact order specifications, is being read. Subsequently, lamps of pick locations of concerning modules, lighten. According to the Poka-Yoke principle. Finally, the filled carrier finds it way to an empty assembly station.
The worker at this station, has to assemble the entire system. After the chip at the carrier has been read (automatically), the complete assembly instruction appears on his/her monitor. Mistakes made in picking the order appear immediately. By scanning the serial numbers of the modules to be assembled by the worker, these are coupled automatically to the serial numbers of the concerning computer system. This way, Tulip keeps up whole of the history of all systems. After completing this assembly, the system will be tested automatically. For defects of modules, plugs not attached properly, etc. Finally, the computer will be installed automatically. The flash EPROM will also automatically be provided with a proper BIOS, and set-up. The final system is therefore really ready to use. By changing from line production to cell production, and by the automated supply of modules, productivity increased by 40% to 60%! The yield of the assembly process has increased from 93% to 96%/97%.
The workers are being trained and educated by Tulip itself. Foremost, they are being thought some quality consciousness. The importance of handling modules right, concerning static electricity. Also finger prints on metal parts should be prevented, even if assembled inside the system. Wires should be rooted neatly, etc. Also, the worker is responsible for the rejection of modules not suiting the quality criteria thought. For instance a cabinet, having a little scratch of only one millimetre should be approved. Yet such a cabinet, having a scratch of a centimetre should be disapproved by the worker. The assembly should be accomplished within a certain time limit. Each worker is provided with feedback of the actual time spent at assembling his or her systems. If this limit is exceeded structurally, the worker will be re-trained. Thus the workers are having more responsibilities then formerly. The current worker actually differs from the old ones, according to Tulip.

So among others, orders are entered by dealers. These are coupled to the computer system of Tulip, by means of SAP, operational since March 3. At this moment, such dealers still have to contact the Tulip factory for checking the availability of all modules needed in delivering all systems asked for. If really ordered, all modules needed will be reserved automatically after releasing this order. This way, the absence of the modules needed when picking these modules for the assembly, will be prevented. Yet, stocks of for instance processors, are greatly limited. In representing the available stocks, the logistic system of Tulip includes floating stocks. Therefore, if something is happening along the way to Tulip, these modules could be absent when needed anyway. A common risk of Just-in-Time delivery. Yet, costs of stocking such costly items, subjected to enormous price fluctuations, and erosions, exceed costs of getting out of stock occasionally amply. Besides, as an extra check, in the morning, the availability of all modules needed that day is checked. This way, planning of assembly can be adjusted if needed.
At the end of this year, the dealer will be able to check the availability of modules himself. The dealer will be integrated entirely to the system of Tulip. Making a phone call superfluous. Also, the dealer is able to watch over the progression of his orders. The SAP system reflects the exact location of his products in production, or distribution.
So Tulip is capable of producing and delivering orders, originating from individual end-users. Tulip is not intending to extend to the living room, by means of the Internet for instance. Yet, their SAP system is already prepared, making reverting to this opinion very easy.
If end-users are faced with problems with his, or her Tulips products, they can consult their dealer. Dealers and other business clients, can turn to a so-called first line help desk. 90% of all problems can be

solved by this help desk. The resulting, more serious problems turn up at the desks of the engineers of Tulip. For instance creating a BIOS up-date.
In case of consulting such a help desk, the possible cause of the problem is exposed on the basis of a faults-tree. Referring to the manual will be sufficient in many cases. In case of real defects, a visit of a mechanic is automatically planned. This mechanic is also automatically provided with all spare-parts needed for solving the problem. A defect board for instance, will be exchanged, and repaired at Tulip. The real defects of such a board will be established there. All problems and defects are entered into Tulip's system, coupled to the serial number of the concerning computer. This way, problems can be carried back to the actual source of the problem. A specific worker, not attaching the plugs properly. Or a drive, of a specific supplier causing problems very often, etc. The latter, if exceeding an agreed percentage of defects, can be taken out of this supplier this way.
Also, the suppliers get feedback of all problems arose anyway, for improvement reasons. In case of a serious problem with certain chips, for instance, engineers will even be exchanged in order to solve the problems as fast as possible. Engineers are sent to the States, or reverse. They realise that serious problems are a threat to both the supplier and Tulip.

The development of new products takes about 6 months. The computers have a life-cycle of 6 to 9 months at a maximum. According to Van de Ven, computers are subjected to technology erosion, not price erosion. For the price of computers remains the same, yet the offerings encompass more and more. On the one side, there's a technology push of companies like Intel. On the other side there's a market pull of software houses like Microsoft, demanding more and more capacity, memory, etc.

Because a product is only produced when specifically asked for, such products manufactured on demand can not be tested extensively anymore. Traditionally, of each product type, a prototype would be made and tested extensively, resulting into completely redesigned prototypes. But now, all products produced are unique. But there is no time for re-designing products, when the end-user is already waiting for the product! Yet, this customer expects the delivery of exactly the product asked for, and functioning properly. Therefore R&D will have to, and does, reckon with this problem, already in the design phase of the product architecture. The computer boards should get along with all the modules offered. That's why Tulip designs for modularity, and why Tulip the R&D department, where 70 people are active, considers to be their key department. When buying modules, the R&D department recognises that all these modules should function in all possible combinations. Tulip buys for quality, commonality, not for price. But they are convinced that this buying for commonality, quality, is also implying buying for the lowest overall costs!
Simulations are used when designing their boards. Based on the by suppliers handed failure-rates, the MTBF (Mean Time Between Failure), can be predicted. In the design phase, suppliers and end-users are also consulted.
By recording all problems, in designing new boards, the engineers can use this data as an input in constructing the successors. Pareto-analyses for instance, can uncover the weaknesses of the old designs.

Price erosion in the computer market, the capability of customising computers, and the, besides prognosticated, reductions of stocks and associating costs, were Tulip's drivers in changing from Manufacturing-to-Stock to Manufacturing-to-Order. Even though only 10% of Tulip's offerings are really divers, margins are considerably higher in this segment! Moreover, this 10% is valued enormously. In case of huge orders, the bulk is all standard. Yet these few systems to be customised, persuade customers. Customers appear to be very enthusiastic about Tulip's customising capability. Expressed into a considerable increase of sales, also of the standard segment. The latter, 90%, can be produced much cheaper now also, as a result of, among other things, the increase of stocks. Moreover, the product-life-cycle of computers, as stated, is very short. Therefore, a company should be present, above all, in the first two months, when margins are still high. Because manufacturing is demand activated now, this can be

achieved now. Besides, the client was no trigger in changing to the current system. They were not asking for more variety, or even customisation! Yet, they are very pleased now! The only driver was the reduction of costs, and the expected, and realised, increase in sales by offering the principle of customising computers.
Tulip considers the layout of the assembly (cell-production), the advanced logistic SAP system, and the fitting of the product architectures for customisation, by means of modularity and by the early qualification of modules, to be the main enablers of this DAMA system.

6.2.2 Discussion

Let's compare Tulip to the insights attained in chapter 5. How well do the findings of that chapter correspond to the real case example of Tulip above. First, the main findings of mass customising products will be discussed, and compared. To this, the main findings of mass customising products of paragraph 5.3 are repeated here first in table 6.1.

Table 6.1: Summary of the pizzeria metaphor findings.

Summary of the main findings of mass customising products	
1.	Quality is determined in interaction with the end-user at the dealer.
2.	Uncertainty of the final product outcome, because of the absence of the tangible product, with virtuality as a possible solution (partly).
3.	Challenge; making product attributes programmable (partly), making modularity also less essential.
4.	Presence necessity of the customer in initiating, and terminating the customisation process, with Internet as a potential solution in some cases.
5.	Managing demand fluctuations, through marketing actions, and by applying traditional waiting theories. Necessity of having over-capacity.
6.	Changed function of the sales process, selling capacity.
7.	Feedback at sales in re-adjusting the offered scope of existing architectures. Feedback of Lead-Users in designing the right platforms.
8.	An adjusted QFD tool, for defining ranges of specifications for a platform design.
9.	Applying platform designs for attaining economies of scale and scope simultaneously, as well as commonality for keeping the diversity manageable.
10.	Product architectures should be 'DAMA-enabling', for instance by means of modularity, and open architectures.
11.	In dynamic markets, buy for quality, if affordable, whenever there's no evidence that buying for price will *really* result into lower overall costs.
12.	Re-consideration of the location of various manufacturing, customisation steps.
13.	Economies of scale is (still) attained at the component, module level.
14.	Limited presence of components, modules stocks. Absence of finished products stocks.

- **1:** In the business-to-business market, these huge clients know exactly what they want, or at least they will pretend they do. But for the private user, a proper determination of the specifications really needed is indeed a difficult matter.
- **2:** The problem of uncertainty of the final product outcome is very small in the computer business. The users of computers are mostly well educated. They know pretty well what to expect from their product. Especially the large amount of huge business clients of Tulip. Also because of the enormous diffusion of computers, potential users are able to watch these products everywhere. This way, they can compare the potentials of those systems to their desires. The problem of private users, confronted with a computer not fulfilling their desires after all, is not due to the absence of a tangible product when buying it.
- **3:** The computer is a clear example of a product, of which attributes are made programmable. Modularity allows for Collaborative Customisation. But the customised computers can be customised

even further at home. Of course, by upgrading the systems hardware. Yet, especially by picking, and installing the desired software, from an almost infinite diversity offered. The latter is what paragraph 4.4 describes as Adaptive Customisation.

- **4:** The customer can phone its order to the dealer, or directly to Tulip. Yet, if wanted, they can also enter the dealership. Orders are delivered at an end-user, a huge business client or the dealer. The end-user should get its products at the dealer, or ask for delivery at home. Their SAP system has already been prepared, for initiating the customisation process by the Internet.
- **5:** In order to manage demand fluctuations, Tulip has 30% of its capacity reserved for rush orders, thus having over-capacity actually. Further, by spreading orders in time, the resulting 70% can be utilised more effectively. If demand fluctuations exceed normal, so called flexpoolers can be called up within 24 hours.
- **6:** For Tulip has already sold their products to be manufactured, sales efforts are indeed focused at the order taking process. When selling products, no specific actions are made related to the occupation of capacity at that moment. For instance adjusting the price. But this does not imply that they should not think about it.
- **7 & 8:** The computer is indeed a, very clear, example of a platform design. Ranges of specifications are set, as well as the scope also this way. Besides, the scope offered by computer architectures is almost infinite. As discussed, seldom the requests fall outside this offered scope. Yet, if even so, the platform does account for it. Only different modules will have to be purchased. Thus, in the computer business it appears to be, that the completion's of those platform designs, the computer architectures, can economically be provided with a scope, larger than asked for. If demands threaten to go beyond the possible scope of the architecture, a new platform, and architecture should, and are indeed already available.

  Also, the longer cyclic design processes of Tulip are customer focused. In the design phase, suppliers and end-users are already consulted.
- **9:** The motherboards of Tulip are as the pizza bottoms for the pizzeria. This way, economies of scope is achieved, because the platform allows a huge diversity of modules to be combined almost infinitely. And without the need for changeover, as with the typewriter metaphor of paragraph 4.2. Economies of scale can be achieved also at the modules level. The platform allows also for commonality, keeping diversity of components and modules manageable.
- **10:** It's overly clear to Tulip that the architectures should be DAMA-enabling. That's why Tulip designs for modularity, and why Tulip the R&D department, where 70 people are active, considers to be their key department. Tulip considers the fitting of the product architectures for customisation, by means of modularity and by the early qualification of modules, to be one of the main enablers of their DAMA system. It allows the computer to be manufactured timely. The computer is also a clear example of an open architecture. Therefore, there is a huge amount of potential suppliers to choose from, making it much easier for Tulip to find timely qualitatively good modules.
- **11:** When buying modules, the R&D department recognises that all these modules should function in all possible combinations. Vagueness of the final product outcome, makes that the computer boards should get along with all the modules offered. Therefore, Tulip buys for quality, not for price. But they are convinced that this buying for quality, is also implying buying for the lowest overall costs!
- **12:** Tulip assembles, customises, all their products centrally in s'-Hertogenbosch, the Collaborative Customisation approach. The Adaptive Customisation is executed mostly at home, by the end-user.
- **13:** The cabinets, components, and modules are all purchased. Their suppliers are large companies, producing at large scale, thus still attaining economies of scale.
- **14:** Because Tulip is an actual demand activated manufacturer, stocks of end-products are inherently absent. Stocks of components and modules have been reduced by the drastically improved forecasts, and its feedback of actual sales, resulting into a much better planning and purchasing process. This way, as mentioned, stocks have already been reduced from Fl. 120 million to Fl. 45 million.

Comparing the findings of paragraph 5.3, shows indeed a remarkable resemblance to those of Tulip. Now the in chapter 5.5 discussed processes of flexible organisations will be compared to those of Tulip. To this, these characteristic processes will be repeated here also, see table 6.2 below.

Table 6.2: Comparing mass producing organisations to mass customisers.

Process characteristics Mass producer	Mass customiser
Compartmentalisation	Decompartmentalisation, time acceleration
Technology focus	Market focus, customer orientation
Vertical organisation structure / Aggregation of the value chain	Networked, virtual organisation structure / Disaggregation into business cells
Supplier certification	Suppliers are virtual partners
Hierarchy of approvals , working alone	Empowerment, working in teams
Job skills required	Multi-dimensional business skills required

- Decompartmentalisation, time acceleration: Tulip has succeeded in drastically speeding their processes. By working with extremely flexible *people*, instead of for instance robots, set-up times are eliminated. Instant communication linkages, and common databases are also required according to paragraph 5.5. Moreover, each link in the chain should know not only what is desired by the next link but what the real demand, the real wants and needs of real customers, are at the end of the chain. Tulip has accomplished all of that by implementing SAP successfully. Tulip considers this advanced logistic SAP system, to be one of the main enablers of their DAMA system. All this has allowed Tulip, to reduce the process lot size to one, to become a mass customiser indeed.
- Market focus, customer orientation: Tulip appears to be just an *order* driven manufacturer, instead of a real end-user oriented, *demand* driven manufacturer, see paragraph 4.5.2. Because Tulip serves only business clients, not end-users. Yet, they are also capable of producing and delivering an order from a dealer, of *one* single system, originating actually from *one* individual end-user. Therefore, this end-user is actually triggering production, thus a real demand activated manufacturer after all. And, as discussed, the longer cyclic design processes of Tulip are also customer focused. In the design phase, suppliers and end-users are already consulted.
- Networked, virtual organisation structure / Disaggregation into business cells: It was discussed that huge hierarchies are unsuited to turbulent environments that reward fleetness, agility, and responsiveness. But Tulip did not have to disaggregate, for they were already such a small business. They have, indeed, focused on their core processes, the assembly of computer systems. Their cabinets are produced by thirds. Their components, and the modules also.
  As discussed, their current flexible system is capable of offering an enormous scope. It exploits economies of scope to a maximum. But, this system is also capable of producing the standard part of orders at lower costs. Thus, Tulip is, indeed, capable of exploiting both economies of scale and scope to a maximum, simultaneously.
- Suppliers are virtual partners: Tulip considers their suppliers as virtual partners. When for example problems arise with supplied chips, engineers of both companies will be exchanged, if needed. Just as in the examples of IKEA, and Toyota in paragraph 5.5.
- Empowerment, working in teams: The assembly workers have been empowered at Tulip. They are responsible, and accountable for assembling the entire system. Formerly, they were not accountable, and were only responsible for assembling the system partly. They are also responsible for the rejection of modules not suiting quality criteria thought. Formerly, this was only reserved for their superiors.
- Multi-dimensional business skills required: The assembly people differ clearly from their colleges in the former MP system. Now, they should have knowledge of all modules to be assembled possibly. Due to having to assemble the entire system, and because of the increased diversity of modules to be

assembled. Therefore, they will be trained by Tulip itself. They are also thought some overall responsibility and quality consciousness.

Tulip has confirmed that their only driver for becoming a mass customiser, was the reduction of costs, combined to the expected, and actually realised, increase in sales. They turned into a mass customiser 'automatically', see paragraph 5.5. I found that the discussed process characteristics of mass customisers, are actually, and clearly, present at Tulip. Therefore, the attained insights of chapter 5, appear to be reasonably correct. Now, these insights can be used in looking at flexibility at Philips.

6.3 Flexibility at Philips

The real case example of Tulip, has indicated the practical value of the findings of chapter 5. After having looked at this real mass customiser, a fairly good image of the flexible organisation has been attained. Philips Sound & Vision wants to improve their logistic performances also. To this, the FIL Supply Chain Management project has been raised. Now let's look to what extent this project is aiming at achieving flexibility, and how Philips expects to realise the goals they aim for. Paragraph 6.3.1 will describe this FIL project briefly.
With the execution of this FIL project, a new value chain model will be constituted. This new value chain is particularly interesting for finding out to what extent Philips is aiming at flexibility. So, to give insight into this new value chain, the key processes Front Office (FO) and Back Office (BO) will be discussed here more thoroughly in paragraph 6.3.2. Finally paragraph 6.3.3 will compare the process improvements FIL aims for, to the attained insights regarding to flexibility of chapter 5. It will be discussed that, and how Philips should incorporate the principle of MC, in order to really achieve World Class Performance.

6.3.1 The FIL Supply Chain Management project

On July 25, 1996 the Board of Management of Philips revealed that developments in the industry and the markets of Consumer Electronics require a structural realignment of the Philips Sound & Vision activities. This could be read in a letter written by CEO Sound & Vision D. J. Dunn [49], see Annex 4.

They decided to embark on a major profit improvement programme. It had to result in a substantial reduction of the operational cost and cost of materials. This objective should be realised by a fundamental change of the ways of working in the total business chain from supplier to customer. Among other things, these different ways of working relate, according to Dunn [49], to the following actions:

- To work with global product concepts for the development of products.
- That are produced with standardised manufacturing processes.
- In which, as much as possible, standard components are used, purchased from a restricted number of selected suppliers.
- Which also has to result in a considerable increase of the manufacturing flexibility and the delivery reliability of the factories.
- This to be supported by globally standardised logistic operations and information technology systems.
- Together with a better interlinkage of the marketing function with the industry.
- And a sustainable reduction of the selling expenses.

Apart from the above, profit improvements should be realised by developing, producing and selling of new products for the consumer.

FIL is one of the improvement processes. The assignment of the FIL management team is to ensure that the total integration of the supply chain will be brought on World Class Performance.
According to Pelzers [51], the overall goal of Philips is to make money for the shareholders, both now and in the future. To do this, customer service should be improved to ensure satisfied customers, and this required customer service level should be realised at the lowest possible integral cost. According to Pelzers [51], this means for the logistic performance that you need an improved customer service coupled with a reduction of logistics and information technology costs. And this improvement must be concentrated on customer requirements. Because he realises, that the days when every customer was treated in the same way are long gone. Demands become more and more specific and service needs to be tailored to the requirements of particular trade channels.

Table 6.3: The long-term vision from Sound & Vision's supply chain management. (Pelzers [49]).

The long-term vision for Sound & Vision's supply chain management
■ To electronically integrate Sound & Vision's total enterprise supply chain, giving total visibility to management. ■ To achieve real-time supply chain management in practice. ■ To ensure most, if not all, manufacturing is Make-to-Order based on end-user demand. ■ To actively manage finished goods inventory for most, if not all, Sound & Vision customers.

In order to do so, FIL guiding principles have been derived from the long-term FIL vision and the targets which must be achieved. These have been drawn up for logistics, finance & accounting, warehousing and distribution, purchasing and information technology. The logistic principles, of particular interest in the scope of this assignment, are stated below.

Table 6.4: Logistics guiding principles for Sound & Vision (Pelzers [51]).

Logistics guiding principles for Sound & Vision (World Class Performance)	
1.	The prime objective for the supply chain is to provide required customer service.
2.	The required customer service has to be realised at the lowest possible integral cost in the whole supply chain, including suppliers and customers.
3.	Logistics and financial control must be integrated.
4.	Synchronisation of supply and demand capacities should be managed according to: ■ Push principles - medium term. ■ Pull principles - short term.
5.	Real demand must be clearly visible throughout the supply chain.
6.	No customer orders - no bundling.
7.	Lost sales are lost sales.
8.	Holding on inventory will be as far upstream as possible.
9.	Minimise movements of products between bundling and customers to 'one move' unless.
10.	Flexibility will be improved by significant increases in component and product commonality, minimising lead times and eliminating firm horizons.
11.	Significant improvements in sales reliability and in supply reliability are necessary for realising customer service objectives.

The next step in the FIL project, is a high level business model, showing how the business has to be steered in the future. This high level business model divides the processes into a number of key processes. These are sales and operational planning, industry, front office, back office, service, purchasing, warehouse and distribution, and finance & accounting. These are the main activities within the supply chain. This business model will, according to Pelzers [51], together with the guidelines and principles for logistics, lead the Sound & Vision organisation in the supply chain towards World Class Performance! Every Line Of Business (LOB) and every business group has a business plan, the starting point in this

high level business plan. The industrial manager will be responsible for where and how to produce, but the LOB is responsible for what to produce and when. The LOB also directs the regions on what to sell and for what price.
This business plan feeds into a sales and operational planning process. A monthly process managed by the BPTs. It not only includes information from the LOB business plans, but also the amount of capacity installed in the factories, and new forecasted sales with their input from customers. At the moment, this is a monthly process. Yet, unplanned daily occurrences must be allowed for on a daily basis. For example: There's a promotion for a product and Philips thinks it will sell 3000 units in two weeks. But they've not even sold 300 in half that time. In the old process, you had to wait a month to adjust these things. After the implementation of the FIL project, they will be constantly adjusted, according to Pelzers [51].
Once this dynamic operational scheduling process is in place, then there is one set of agreed plans. Daily orders from OEMs and customers are matched against what has been agreed. The orders have to fit within agreed capacities. As the orders are accepted within the planning process, they go into order execution. Either to a bundling factory, where they are made and sent directly to the customer, to a factory distribution centre, or to local distribution points (Pelzers [51]).

The integration of the supply chain will be achieved by the implementation of SAP/R3. One of the advantages, according to Pelzers, is that this is a proven system, already in use in many of the 500 top companies of the world, such as Unilever, Proctor & Gamble, and Sony.
In the past, Philips developed its own systems. But this took so long that by the time they were in use they were already more or less out-of-date. And everyone was using different systems. Now, one common system results in far lower maintenance costs and a much greater consistency in data. Communication throughout the company becomes faster and eliminates misunderstandings, because everything is unambiguous (Pelzers [51]).

Our target date is 2000, the same year that the next Olympics will be held. We can compare our project with the battle faced by the athletes who want to win a medal. . . . . .They will only be satisfied by becoming world champions in 2000. Exactly the same applies to us and we will not be satisfied unless we achieve World Class Performance." (Pelzers [50]).

Their target is 2000. However, according to the table below, the full implementation of all entities is planned in the beginning of 2005.

Table 6.5: Magnitude of project SAP/R3 (Pelzers [49]).

	Number of implemented entities	% of T.O. covered
01-01-1998	5	2
01-01-1999	15	**20
01-01-2001*	65	**60
01-01-2005*	150	100

* Two entities per month.
** Depending on implementation priorities.

6.3.2 The Front Office & Back Office

With the execution of the FIL project, a new value chain model will be constituted. This value chain is particular interesting in finding out to what extent Philips is aiming at attaining flexibility. So, to give insight into this new value chain, the key processes Front Office (FO) and Back Office (BO) will be discussed here more thoroughly. Figure 6.1 below illustrates the positioning of the FO and BO in this new value chain model.

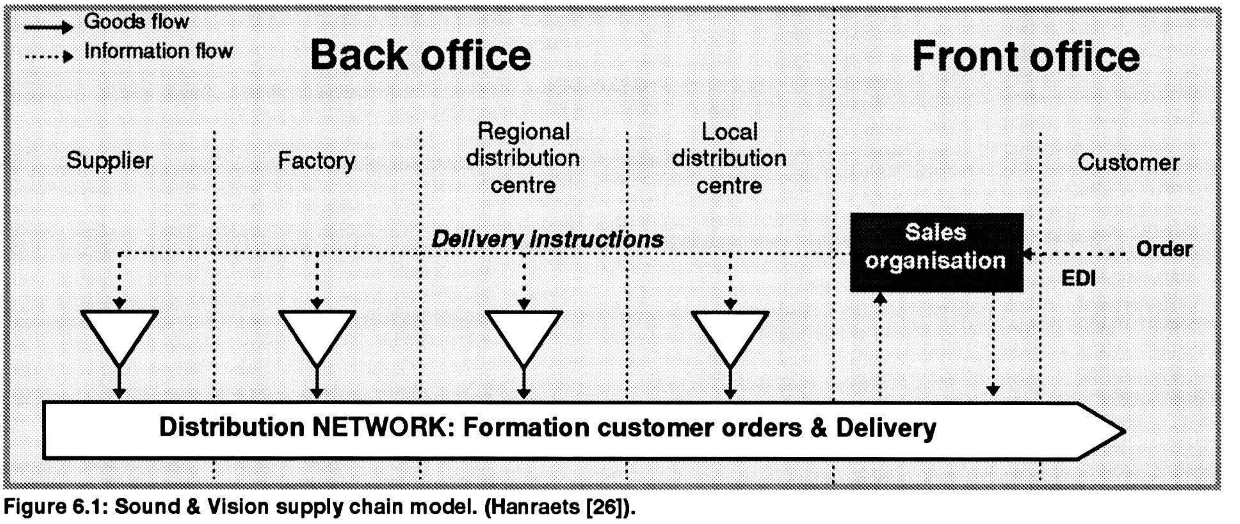


Figure 6.1: Sound & Vision supply chain model. (Hanraets [26]).

Generally speaking the FO is responsible for the following business processes:
- Sales planning (bottom up and top down).
- Sales activities.
- Order management.
- Financial management (National).

BO is responsible for all the business processes covering:
- Inventory management.
- Store & delivery of finished goods.
- Goods receipt management.
- Information systems and services.
- Financial accounting and services.

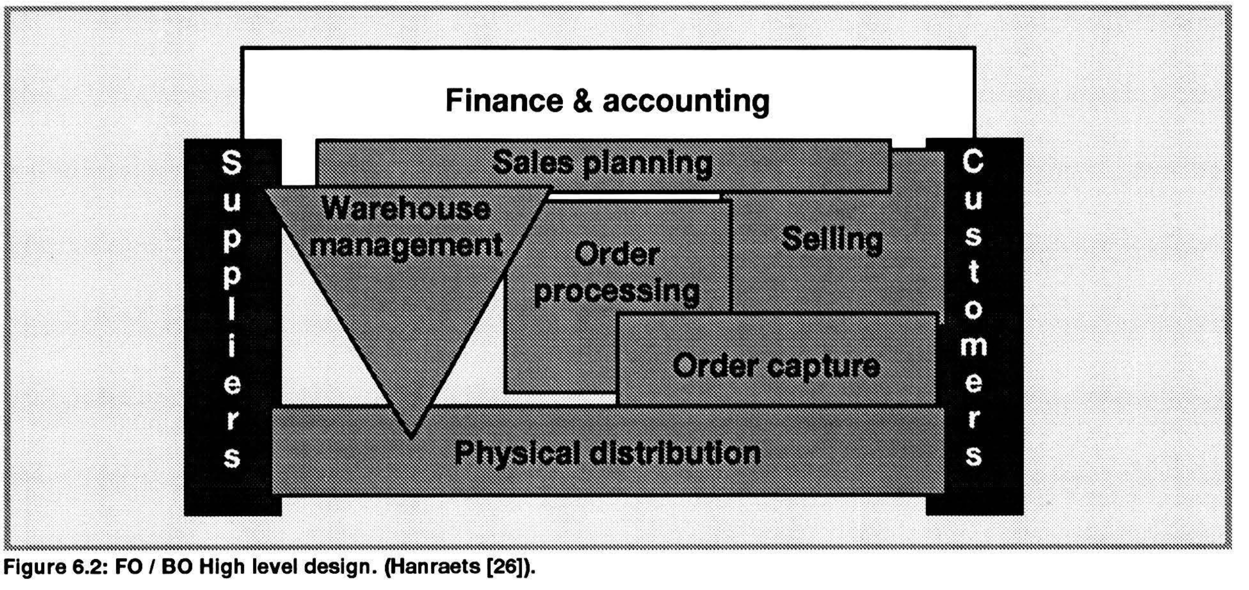


Figure 6.2: FO / BO High level design. (Hanraets [26]).

From the Logistic guiding principles, table 6.4, FO / BO guiding principles have been derived by the FIL platform. Here, the most important principles towards flexibility will be discussed.

■ Customer oriented approach.
-With the prime objective to provide the required customer level at the lowest integral cost.
-The operation as one face to customer where possible and / or necessary.
-Set up of EDI interfaces with customers. (e.g. order entry, invoicing, order status inquiries, order confirmation).

■ Create simplicity and uniformity in ways of working.
-By reducing diversity of product range in the market (e.g. fewer TV types).
-High flexibility required at mix level.
-Short term flexibility at volume level is restricted to changes to the agreed plans only.
-Increase commonality at product level over national versions.
-Standardisation and simplification of the pricing and delivering conditions.
-Regional promotion strategy. Reduce national defined promotions to a minimum. NSO's will be aggregated into RSO's.
-Clear brand policy by allowing second brand distinction by identification only.
-Implementation of single customer classification within Europe.

■ As less as possible stock points in the supply chain.
-Decrease / eliminate stockholding for certain products in multiple places in the supply chain.
-Delivery from stock points to third party distribution networks as much as possible.
-Direct deliveries from (European) factories to customers where possible.
-In the generic supply chain model the following four distinct supply chain flows can be recognised:
▪ Make-to-Stock (finished goods) - Ship-from-Stock. This is planning driven production and supply model.
▪ Make-to-Stock (sub-assemblies) - Assemble-to-Order. This is planning driven production but demand driven assembly model.
▪ Make-to-Order finished goods. This is demand driven production model.
▪ Make-to-Order sub-assemblies. Currently S&V is not in the business of selling sub-assemblies.

■ Increase flexibility to the market.
-Offer variety in delivery services. Like differentiation in order cycle times, and differentiation in delivery models (delivery to retail <> delivery to consumers).
-Offer variety in ordering services. Like order capture with customers and EDI.
-Offer additional services. Like information and packaging.

■ Lowest cost to serve (integral costs).
-Every step in the order processing chain need to be evaluated against their added value.
-Pressure to deliver in smaller quantities to be critically reviewed against the integral cost-benefit analysis.
-Focus on cost to serve.

■ Well defined responsibilities.
-BPT's (LOB's) are responsible to define required distribution policies and manage stock levels at medium and longer term.
-NSO (FO) is responsible to define the customer requirements and manage the short term sales plan.
-BO is responsible to provide services against competitive costs and service levels.

6.3.3 Discussion flexibility at Philips

Thus Philips aims at ensuring satisfied customers, by bringing S&V to World Class Performance. But it has been discussed in the previous chapters, that companies, like Benetton, Compaq, Matsushita, Motorola, Nissan, Toyota, and Tulip, consider Mass Customisation to be the key principle, in really satisfying customers. Their vision and current actions go far beyond the conventional marketing functions and principles. I expect that in 2005, many of these companies will be capable of fully mass customising products. After all, by then many of them will really be practising (and not being engaged into) the principle of Mass Customisation already for 15 years! Also, already 500 top companies of the world, have currently implemented SAP successfully. It can also be expected that many of *these* companies will be capable of mass customising products in 2005. Thus in achieving the desired goal of becoming World Class in the dynamic markets of S&V in 2005, DAMA should definitely be present in the future models.

Philips wants to ensure that most, if not all, manufacturing is Make-to-Order based on end-user demand in the future, see table 6.3. But it is not clear, how the FIL changes proposed, should accomplish this. For these changes appear to be not far-reaching enough, in order to accomplish that, for instance:

- Customers in figures 6.1 & 6.2 are not real end-users, yet huge dealers, or OEM clients.
- Pelzers [19] wants to tailor service to the requirements of trade *channels*.

The following change appears to be even contrary to the fundamental principles of Mass Customisation:

- Philips is *aggregating* their marketing function, by transitioning their NSO's into a few RSO's.

The changes proposed, with the implementation of SAP centrally, seem to fit the process improvements discussed in chapter 2 mainly. Important improvements, but just partly enabling Mass Customisation, as discussed extensively. If Philips really wants to make up their arrears, they will have to be demand activated in 2005 also. Apparently leading to a problem. The implementation of an enabler like SAP, is only realised by 2005 also after all. Yet, 5% of all entities will have been implemented already next year. Thus these entities can start the move to Mass Customisation already in 1998! Let's discuss the most important bottlenecks in becoming DAMA, in order of importance.

- **1:** Most important in starting the move to Mass Customisation, is the implementation of the definition of quality proposed in chapter 1. Quality is the extent to what a product satisfies each customer. Delivering exactly the kind of product or service each consumer wants, conforming to product specifications, in the right amount, at the right time, and for the right price. According to this definition, products being technically perfect, yet not capable of fulfilling customer requirements, are worthless. Only when considering out-of-spec products as being actually waste, the actual cost price, and efficiency of manufacturing systems becomes manifest. This has been discussed in paragraph 4.3.
  The required customer level is the point of departure at FIL, in maximising profits for the shareholders, see table 6.4. Yet the main goal should be in any business, the maximisation of profits (profit driven). Not the minimisation of costs (cost driven). After all, increasing costs can also result into an increase in marketshare and profits. Just look back at the companies mentioned in chapter 2, 3, and 4.
  Defining quality, and costs like this, is something every mass producer should do. Even when not intending to become a mass customiser at all. Nevertheless, if active in dynamic markets, this change will shift that mass producer in the direction of a mass customiser after all. As discussed in paragraph 5.5, it will become evident that changing to the flexible processes of table 5.2, will actually decrease costs. For inflexible processes can result into products having the wrong specifications. In products being waste. By continuously looking for profit improvements, mass producers active in dynamic markets, will resemble more and more to mass customisers. Ultimately becoming one, just like Toyota, Matsushita and Tulip.

■ **2:** The next difficult bottleneck will be the capability of translating ranges of customer requirements into product design. This requires a platform design. And also the capability of producing the customised product within one or few days. Thus requiring product architectures to be 'DAMA-enabling', see chapter 5. Without these capabilities, it is still impossible to offer customised products timely. Yet, only by applying the broadened definitions of costs, and quality, it will be clear that for instance modularity will result into lower overall costs. Tulip has confirmed that they consider this issue to be the most important enabler for Mass Customisation.

■ **3:** But having 'DAMA-enabling' architectures, will not guarantee customer desires to be fulfilled better. The risk of being out-of-spec, of producing waste, is still there. It is essential to have a real customer orientation also. Customer requirements should trigger short cyclic assembly processes, as well as long cyclic development processes. The quality in determining customer requirements properly, determines the product quality. The extent to what the product will actually satisfy the end-user. And for instance feedback of Lead-Users, is essential in managing the scope of platform designs properly. Without these long cyclic processes being penetrated by customers also, designs will probably provide the wrong scope of customisation.

■ **4:** Next important in starting the move to DAMA, is having responsive, slendered processes. Without, it is absolutely impossible to fulfil fast changing customer desires timely. As discussed in chapter 2, these improvements are essential in being capable of coping with an increased competition, increased seasonality, fashion, and other demand variation. By taking more and more time out of the value chain, less and less (floating) stock will be needed. Also, customer requirements can reach the plant almost instantly, by electronically integrating the value chain.

■ **5:** If having platform designs, 'DAMA-enabling' architectures, a customer orientation, and slender processes, the techniques for attaining both economies of scale and scope simultaneously are needed. Yet, attaining these does not appear to be a severe bottleneck. For these techniques are already present at Philips, or they can be bought almost everywhere, pretty 'simple'. Implementing these techniques could possibly bring up (severe?) cultural and organisational problems. Yet investigating this went beyond the scope of my assignment.

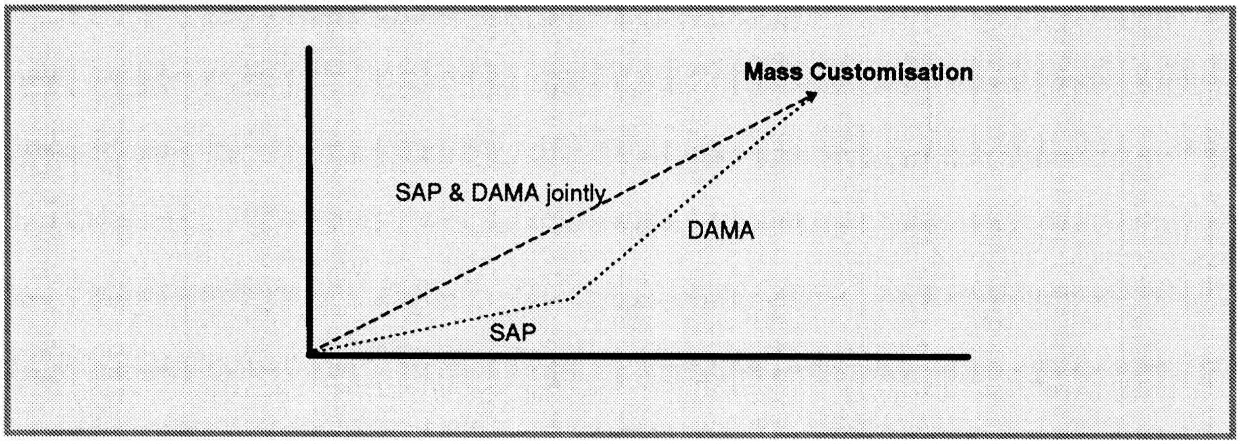


Figure 6.3: Attuning prioritisation's to the two phases jointly, results into the shortest way to becoming a mass customiser.

Thus the way to becoming a mass customiser, consists of two main phases; implementing SAP (first), and implementing DAMA (second). To become a mass customiser as easy, fast as possible, the optimisation priority chosen of the steps to be made, should be attuned to these two phases *jointly*. Optimising the implementation time of the first phase separate from the next phase, will result into sub-optimisation of the total implementation efforts. This has been depicted into figure 6.3 left page, by the length of the dotted lines. Optimising the two phases jointly (although implementing them consecutively), results into the shortest way in becoming a mass customiser.

The following list shows the most important points in becoming DAMA.

- Dynamic market, applying proper quality, cost definitions.
  - Quality programs beyond ISO 9000 (e.g. exchange of engineers among companies).
  - Customer satisfaction is monitored, resulting conclusions are also applied into re-designs.
  - The entity is accustomed to deal with considerable variety.
  - At the first entities to be implemented, market dynamics should not be too high.
- Products are 'DAMA-enabling'.
  - Products should be at least partly modular, but ideally 100%.
  - Product features are at least partly programmable, making modularity less essential.
  - Products have a platform design.
  - Products have open architectures.
- Short as well as long cyclic processes are customer oriented.
  - Feedback of end-user is used in adjusting product designs.
  - Customers are involved in the product creation process (e.g. Lead-Users).
- Flexible, slendered processes.
  - Principles of Lean Thinking are applied.
  - Wholesalers, dealers, plants have been electronically integrated.
- Production allows for economies of scale and scope simultaneously.
  - Autonomous groups, no totally integrated processes (like light bulbs).
  - Machines allow for reasonably fast changeover.
  - Changeover reduction programs (e.g. SMED).
  - Processes are re-useable, commonality of processes.

6.4 Demand activated manufacturing at the Dutch PTT

In chapter 5, the problems and points of attention in manufacturing DAMA products have been discussed. These findings, and process characteristics of DAMA, showed a remarkable resemblance to those of an actual demand activated manufacturer (Tulip). The attained insights of chapter 5, appeared to be reasonably correct. Having in mind these (checked) findings, it has been discussed how Philips should become demand activated.
Yet it remain just theories. Only practical experience will show the real value of these findings in mass customising products by Philips. At Philips, practising the principle of MC, could expose completely unexpected problems. Therefore, it's recommendable to start practising DAMA as fast as possible, in order to put Philips on the learning curve. But start implementing DAMA at the entities discussed is a very complex issue. It will possibly take much time, before Philips will (be able to) start implementing DAMA at these entities. Approvals are needed, and then SAP has to be implemented first.

In order to get onto the learning curve already now, Philips could start less complex DAMA projects. This could be done together with a partner. A service company, having those other competencies needed when mass customising products, besides the mass producing ones. Precisely for this, paragraph 6.4.1 discusses the Telepost services of the Dutch PTT. A service turning electronic mail into physical mail. A real DAMA example, executed by a service company. Next, the theories discussed in this report will be released to this PTT case, in accomplishing an actual, new DAMA proposal. This by extending these Telepost services currently offered by PTT Post.

6.4.1 The PTT Telepost services

Another actual DAMA case is Telepost of the Dutch PTT Post services [l]. This *service* allows you to send them messages, congratulations, electronically, which are then printed, folded, inserted, affixed postage, and send via conventional (snail) mail. These messages can be send 24 hours a day via the Internet, or via Videotex, and are printed on special note-paper. Those entered before 9.00 p.m. are delivered the next day (except for Sundays and holidays). It is also possible to enter a desired delivery date, to a maximum of one year ahead. The costs for sending a regular one page letter is Dfl. 1.50 for the first page, and Dfl. 0.20 per additional page. In order to embellish the congratulation, it is also possible to provide the message, with one of five offered pictures. Payment should take place by means of I-pay, a Dutch Internet payment system.

The advantages to the customers, and the Dutch PTT in comparison with conventional snail mail are among other things:

- It is very easy. A lot of time will be saved, because of not having to print, fold, look for a stamp, insert, post, etc.
- With conventional snail-mail, letters have to be posted at a mailbox before 6.00 p.m., for having it delivered next day. With Telepost this period is extended to 9.00 p.m., without having to leave your home at all.
- There are a lot of people having a Internet account. Yet even more having none. This way, it is possible to e-mail to people not having a computer. Similarly the PTT is offering a Fax-Telepost service, for faxing to people not having a fax.
- Because the messages are printed by the PTT, the costly purchase of printing equipment by the customer becomes superfluous. Printing less costly, because the PTT will attain economies of scale. Moreover, with much better quality, and possibilities, because of having really professional equipment.
- The PTT will save logistic costs. For the mail can be sorted out and routed digitally, before making a hard copy out of it.
- With Telepost, the PTT is provided with extra load, conventional mail to be delivered.
- Hard copy's of congratulations will probably be of more emotional value to recipients, more valuable, than e-mail messages.

At this moment, Telepost allows the messages to be send only within the Netherlands. But there are plans of extending the Telepost services offered. Software programmes like 'PC-epost client' and 'PC-epost server' should enable linked clients to deliver data from each Window application, by only clicking a 'print' or 'message dispatch' icon. This extended service is, at least at first, aimed at the small and medium businesses, having small message volumes (1 to 10.000). Yet end-users are also considered as being possible clients. The Dutch PTT is aiming at introducing this extended Telepost service at the end of 1997, nationally. The concept has to be adjusted for also introducing it internationally.
But there is already a company active internationally. E-snail [b], present at the Internet, is a service for turning your e-mail message into paper mail, sending it all over the world with the United States Postal Services. It allows e-mail messages, as well as attached PC format files, to be send. Also, you can choose from six greeting cards.

6.4.2 Proposal, expanding the PTT Telepost services

The Telepost case shows, that the Dutch PTT is capable of producing, demand activated, customised printed matter, even in lot sizes of one. But at this moment, the PTT is with its current, and future services only focusing at taking over efforts made by private persons, or by administrations of small companies.

Yet, it has been discussed that mass customising service companies are entering markets, formerly reserved to mass producing companies. So by extending their Telepost services, the PTT should not only be able to take away trouble, efforts of their clients, yet to also attack current mass producers of for instance postcards! The latter forms the core of the proposal to be discussed here, the demand activated printing of postcards.
The idea is that people should be allowed to make their own, customised postcards. You enter for example a kiosk, where they would normally buy their postcards. But now, an intelligent piece of software on a terminal allows them to make their own. They can simply choose from existing cards, or adjust them, bring their own digital pictures, scan photos or their handwriting, etc. The terminal could be provided with a digital desk-top camera, allowing them to be depicted in front of for instance the Niagara waterfalls. Also, the card could be equipped with a programmable music chip, allowing to also send sounds, songs, or spoken text. Finally, the card, shown virtually, will be printed and delivered by the PTT. The proposal encompasses all the advantages, discussed already in the preceding paragraph 6.4.1. Where the PTT will earn money by producing and delivering these cards, Philips could develop, and manufacture the terminals for accessing this service.

In chapter 5, the main findings in mass customising products have been derived. So in order to get better insight into this DAMA proposal, let's apply these insights here:

- Remember the definition of quality, stated in paragraph 1.4. It will then be obvious, as discussed in paragraph 5.2, that the quality of a demand activated manufactured postcard should be higher than conventional ones, Manufactured-to-Stock. Yet, this will be determined by the skills of the clerk, as well as by the quality and possibilities of the terminal's software.
- The postcard is not physically stocked at the kiosk. But the client will be shown the virtual card on the monitor, taking away uncertainty about the product outcome, almost certainly.
- The clerk's share in constituting the card, should be reduced to a absolute minimum, for this would make the cards far to costly. Yet ultimately, grandma should be capable of making, and sending a postcard, by using this terminal also. Thus making high demands of the software, guiding the client through the creation of their postcard. For instance by showing a virtual clerk, not distinguishable from real persons. But for the time being, a nice menu will do the job quite good enough.
- Because of the photos, pictures, drawings, etc., being stored digitally, there's indeed far more scope for customisation. And enlarging the scope offered, will be accompanied just by some legal costs. So an enormous database could be attached to this service. The postcards, being stocked virtually, also allow to react to topical subjects very fast. For instance a camera, on top of the terminal, allows you to be portrayed, apparently embraced by queen Beatrix, on 'Koninginnedag' (Queensday).
- The client has to be physical present in initiating the customisation process. This has been chosen for deliberately. An Internet variant could be imagined also, yet implying a completely different approach. Many people still don't have Internet, or even a computer at all. Restricting this service to Internet users, would reduce the potential target group enormously. Also, Philips would not have any interest in this project, for there would be no need for developing, producing any terminals. The Internet variant would aim for completely different clients. Now these terminals can be placed at kiosks, supermarkets, tourist information offices, camping stores, amusement parks, bungalow parks, special sightings, and all other places where people feel the need of sending a postcard. Places where Internet users are not having their computer with them either. And terminals placed outside, provided with desk-top cameras, allow you to be depicted in front of your environment.
- Feedback received by the clerk, can be used in re-adjusting the entire system. Also, the clients could be allowed to enter specific requests, or suggestions.
- The postcard can be considered as a platform design. The blank card, similar to the empty pizza bottom, can be 'provided' with all kinds, of coloured modules, dots. The card can be 'assembled' (printed), in a few seconds. Thus the architecture of the postcard is also 'DAMA-enabling'. And because

it's also an open-architecture, everyone can supply pictures, and photos, even the clients themselves. Allowing the scope of customisation to be increased infinitely.

- The location of the printing device, will be determined by the success of the service. How many systems should be placed, and where, is just a logistic, and arithmetical problem.
- As also mentioned in the 'typewriter' metaphor, current printing systems allow all kinds of pictures, fonts, etc., to be printed, without any need for changeover. The PTT can attain economies of scale and scope simultaneously.
- As with all DAMA systems, stocks of finished products will be absent. Only the blank cards will have to be stocked, yet centrally, clearing up space at the 'dealerships'. The modules, dots, pictures, etc., are all stored digitally.

This has been proposed to PTT Post, who showed themselves very enthusiastic. Now, the AIM (Advanced Interactive Media) team at the ASA-Lab, is looking for an appropriate group within Philips, for participating this DAMA project. A group willing to, develop, produce, and deliver the terminals, and software for accessing this service.
At first, only a few terminals will be needed off course. But ultimately, these terminals could be placed at all possible places. And these terminals, pillars, could be applied for far more applications. Information pillars, placed at railway stations, or airports, could inform tourists, by showing the top 10 restaurants, or sightings, etc. The companies mentioned, will probably finance these pillars with great pleasure.
This report also mentioned companies using suchlike terminals, in creating cars, bicycles, glasses, etc. It can be expected that these terminals will increasingly appear in shops, and dealerships, especially those practising the principle of MC. So developing, and producing these now, even when only one or few, will put you on the learning curve of a product, possibly appearing everywhere in the (nearby?) future.

This project allows you to actually watch the problems in demand activated manufacturing of products. To enter the learning curve of mass customising products right now. This can be very valuable, informative, for Philips, in learning how to mass customise consumer electronics! In start implementing DAMA at the entities as discussed in paragraph 6.3.3.

6.5 Summary

Chapter 5 discussed the points of attention in mass customising products. Characteristics of those products were derived by considering products as services. It was also discussed how the processes of such a demand activated manufacturer should differ from traditional mass producing companies. After having explicated these characteristics and processes, it would be recommendable to check these in practice. To this, Tulip, a computer manufacturer in s'-Hertogenbosch, has been visited. It is one of few accessible practisers of the principle of demand activated manufacturing. Because of resemblance's between Tulip and Philips, the attained insights in visiting Tulip were expected to be very useful, and valuable for comparing these to Philips.
And indeed, the comparison shows a remarkable resemblance between the findings of paragraph 5.3, and those of Tulip. Also, I found that the discussed process characteristics of mass customisers, are actually, and clearly, present at Tulip. Therefore, the attained insights of chapter 5, appear to be reasonably correct. Although, further testing would have been recommendable, yet impossible.
The findings are used in comparing them to flexibility improvement projects at Philips. To improve their logistic performances, Philips Sound & Vision has raised the FIL Supply Chain Management project. With the execution of this FIL project, a new value chain model will be constituted. FIL aims at ensuring satisfied customers, by bringing S&V to World Class Performance. In achieving the desired goal of

becoming World Class in the dynamic markets of S&V in 2005, DAMA should definitely be present in the future FIL models. But it was not clear how the FIL changes proposed should accomplish this. By applying the principles discussed along this report, it has been discussed that, and how Philips should incorporate DAMA, in order to really achieve World Class Performance.
Yet it remain just theories. Only practical experience will show the real value of these findings in mass customising products by Philips. At Philips, practising the principle of MC, could expose completely unexpected problems. Therefore, it's recommendable to start practising DAMA as fast as possible, in order to put Philips on the learning curve. But start implementing DAMA at the entities discussed will probably take much time. In order to get onto the learning curve already now, Philips could start less complex DAMA projects. This could be done together with a partner. A service company, having those other competencies needed when mass customising products, besides the mass producing ones.
Precisely for this, the Telepost services of the Dutch PTT have been discussed. A service turning electronic mail into physical mail. A real DAMA example, executed by a service company. Next, the theories discussed in this report have been released to this PTT case, in accomplishing an actual, new DAMA proposal. This by extending these Telepost services currently offered by PTT Post. Executing this proposal in partnership with the Dutch PTT, can not only be very rewarding itself, yet could also be very valuable, and informative, in learning how to mass customise products in the future.

7 Conclusions & recommendations

7.1 Introduction

In this final chapter a summary of the main conclusions, paragraph 7.2, and recommendations, paragraph 7.3, made along this report will be given.

7.2 Conclusions

- As products get more mature, customer requirements become tougher and tougher. More and more features have to be accounted for, in order to attain the same level of perceived quality. In order to still be able to distinguish from competitors, it will even be necessary to manufacture products to the specific needs of each individual customer. This asks for a dramatic increase in overall flexibility of mass producing companies, active in these dynamic markets. And as has been depicted in figure 1.1, this call for more flexibility can not be ignored.

- Demand Activated Manufacturing Architectures (DAMA), should not be confused with Assemble-to-Order, or Produce-to-Order systems, known and applied for already a long time. The orders in such order driven systems contain many products of the same type, requested within a certain length of time. The demand in demand driven systems is the instant request for one specific product by one specific end-customer. DAMA systems are really a lot more demanding of an production organisation, than these conventional Manufacturing-to-Stock and even -to-Order systems.

- Most important in starting the move to Mass Customisation, is the implementation of the definition of quality proposed in chapter 1. Quality is the extent to what a product satisfies each customer. Delivering exactly the kind of product or service each consumer wants, conforming to product specifications, in the right amount, at the right time, and for the right price. According to this definition, products being technically perfect, yet not capable of fulfilling customer requirements, are worthless. Then, the Transformation Factor, shows that Mass Customisation can be far more efficient in dynamic markets. Where the mass customisers mostly, at least presently still!, lose *some* time by changeover, the mass producer appears to lose far more time by being out-of-spec! Waste is produced, actually. In calculating a product's cost price, *technical* poor products, as well as out-of-spec products should be considered as being waste, as in formula 4.6. The inputs of formula 4.6, should include the after sales costs, the costs of satisfying the customer within the period of guarantee offered. Only then, the actual cost price, and efficiency of manufacturing systems becomes manifest.

(4.6) Cost price product = value of all inputs / # products sold =
value of all inputs / (# products produced - # technical waste - # products not sold).

- When production gets demand activated, the end-user gets actually involved in the production process. Products are tailored to meet the needs of individual customers, just as with intangible services. DAMA products, have this same characteristic as a service. Producing what the consumer desires, is something what manufacturing companies are not, but service organisations are familiar with. Thus, just having excellent mass producing capabilities, will not be enough, for manufacturing, and delivering *customised* products properly. It could (should) *also* require to have the capabilities of a top service company. Therefore, companies having a core competency in producing and selling huge amounts of the same boxes, like many parts of Philips for instance, could face problems when offering customised ones. For this, the capabilities of a service company are required also.

■ To understand this mix of competencies better, the differences between DAMA and traditional Manufacturing-to-Stock systems have been clarified. To this, a metaphor of a service company, the customising pizzeria, has been used. The service metaphor resulted into valuable findings, summarised in table 7.1, with regard to (the quality of) the customisation of products. Comparing these findings deduced from a service metaphor, to those of an actual demand activated manufacturer (Tulip), showed a remarkable resemblance.

Table 7.1: Summary of the pizzeria metaphor findings.

Summary of the main findings of mass customising products	
1.	Quality is determined in interaction with the end-user at the dealer.
2.	Uncertainty of the final product outcome, because of the absence of the tangible product's 'touch and feel', with virtuality as a possible solution (partly).
3.	Challenge; making product attributes programmable (partly), making modularity also less essential. To be discussed further on.
4.	Presence necessity of the customer in initiating, and terminating the customisation process, with Internet as a potential solution in some cases.
5.	Managing demand fluctuations, through marketing actions, and by applying traditional waiting theories. Necessity of having over-capacity.
6.	Changed function of the sales process, selling capacity.
7.	Feedback at sales in re-adjusting the offered scope of existing architectures. Feedback of Lead-Users in designing the right platforms.
8.	An adjusted QFD tool, for defining ranges of specifications for a platform design.
9.	Applying platform designs for attaining economies of scale and scope simultaneously, as well as commonality for keeping the diversity manageable.
10.	Product architectures should be 'DAMA-enabling', for instance by means of modularity, and open architectures.
11.	In dynamic markets, buy for quality, if affordable, whenever there's no evidence that buying for price will *really* result into lower overall costs.
12.	Re-consideration of the location of various manufacturing, customisation steps.
13.	Economies of scale is (still) attained at the component, module level.
14.	Limited presence of components, modules stocks. Absence of finished products stocks.

■ But, organisations have to differ from traditional mass producing organisations, in order to be capable of mass producing such 'service-like', customised products. Table 7.2 embraces these main differences between the inflexible Mass Production systems, and the flexible, Mass Customisation systems. I found that these process characteristics of mass customisers, are actually, and clearly, present at Tulip.

Applying the definitions of quality, and costs as discussed, will shift mass producers in dynamic markets in the direction of mass customisers. And, ultimately becoming one. Even when not intending to become a mass customiser at all. For in dynamic markets, inflexible processes result into products having the wrong specifications. In products being waste. Flexible processes actually decrease costs. Companies like Toyota and Matsushita for instance, are definitely not aiming at becoming a mass customiser, chasing some higher goal. No, by defining costs, and quality different as traditionally in mass producing environments, they obtain the mass customising processes of table 5.2. They turn into mass customisers almost 'automatically'!

Tulip has confirmed that their only driver for becoming a mass customiser, was the reduction of costs, combined to the expected, and actually realised, increase in sales. They turned into a mass customiser 'automatically'.

Table 7.2: Comparing mass producing organisations to mass customisers.

Process characteristics	
Mass producer	Mass customiser
Compartmentalisation	Decompartmentalisation, time acceleration
Technology focus	Market focus, customer orientation
Vertical organisation structure / Aggregation of the value chain	Networked, virtual organisation structure / Disaggregation into business cells
Supplier certification	Suppliers are virtual partners
Hierarchy of approvals , working alone	Empowerment, working in teams
Job skills required	Multi-dimensional business skills required

■ Philips aims at ensuring satisfied customers, by bringing S&V to World Class Performance. But it has been discussed that companies, like Benetton, Compaq, Matsushita, Motorola, Nissan, Toyota, and Tulip, consider Mass Customisation to be the key principle, in really satisfying customers. Their vision and current actions go far beyond the conventional marketing functions and principles. I expect that in 2005, many of these companies will be capable of fully mass customising products. After all, by then many of them will really be practising (and not being engaged into) the principle of Mass Customisation already for 15 years! Also, already 500 top companies of the world, have currently implemented SAP successfully. It can also be expected that many of these companies will be capable of mass customising products in 2005. Thus in achieving the desired goal of becoming World Class in the dynamic markets of S&V in 2005, DAMA should definitely be present in the future models.
Yet, the FIL changes proposed, with the implementation of SAP centrally, seem to fit the process improvements discussed in chapter 2 mainly. Important improvements, but just partly enabling Mass Customisation. The changes appear to be not far-reaching enough. If Philips really wants to make up their arrears, they will have to be demand activated in 2005 also.

■ Mass Customisation requires the capability of translating ranges of customer requirements into product design. This requires a platform design. And also the capability of producing the customised product within one or few days. Thus requiring product architectures to be 'DAMA-enabling'. Without these capabilities, it is still impossible to offer customised products timely. Yet, only by applying the broadened definitions of costs, and quality, it will be clear that for instance modularity will result into lower overall costs. Tulip has confirmed that they consider 'DAMA-enabling' architectures to be the most important enabler for Mass Customisation.

■ But having 'DAMA-enabling' architectures, will not guarantee customer desires to be fulfilled better. The risk of being out-of-spec, of producing waste, is still there. It is essential to have a real customer orientation also. Customer requirements should trigger short cyclic assembly processes, as well as long cyclic development processes. The quality in determining customer requirements properly, determines the product quality. The extent to what the product will actually satisfy the end-user. The extended Quality Function Deployment tool can be applied to translate the voice of the customer into families of products. This way, the scope and range of customisation, can be optimised for the greatest potential of success in the marketplace without wasted effort for unnecessary customisation. And for instance feedback of Lead-Users, is essential in managing the scope of platform designs properly. Without these long cyclic processes being penetrated by customers also, designs will probably provide the wrong scope of customisation.

■ Without having responsive, slendered processes, it is still absolutely impossible to fulfil fast changing customer desires timely. Applying the principles of Lean Thinking, OPT, and Time-based Competition, can result into the essential improvements, for being capable of coping with an increased competition, increased seasonality, fashion, and other demand variation. By taking more and more time out of the value chain, less and less (floating) stock will be needed. Also, customer requirements can reach the plant almost instantly, by electronically integrating the value chain.
The product creation process can be speeded by applying virtuality tools. Rapid Prototyping, and Virtual Manufacturing approaches, reduce cycle times and costs in product development, while allowing quality to be increased. And according to users of Virtual Prototyping tools, test results on physical prototypes match these simulations to a very high extent.

■ If having platform designs, DAMA-enabling architectures, a customer orientation, and slender processes, the techniques for attaining both economies of scale and scope simultaneously are needed. Yet, attaining these does not appear to be a severe bottleneck. For these techniques are already present at Philips, or they can be bought almost everywhere, pretty 'simple'. But implementing these techniques could possibly bring up (severe?) cultural and organisational problems. Investigating this went beyond the scope of my assignment.

■ The effects of the Virtual Value Chain, together with the opportunities which Flexible Manufacturing Systems offer, make that the competitive advantages of the larger companies in respect of their small rivals, fade away. Small companies are now allowed to achieve low unit costs for products and services dominated by big companies. The small and medium 'service' companies could even have a comparative advantage in following market wishes flexibly and actively, according to Mastenbroek [44].

7.3 Recommendations

■ People, after having read this report, still calling the Star Trek utopia from the front page total nonsense, risk to join, in the (nearby?!) future, the people having made the bloopers listed below:

■ I think there is a world market for maybe five computers, Thomas Watson, chairman of IBM, 1943.
■ Heavier-than-air flying machines are impossible, Lord Kelvin, president, Royal Society, 1895.
■ 640 K ought to be enough for anybody, **Bill Gates, 1981!.**
■ We don't like their sound, and guitar music is on the way out, Decca Recording Corporation, rejecting the Beatles, 1962.
■ The wireless music box has no imaginable commercial value. Who would pay for a message sent to nobody in particular? David Sarnoff's associates in response to his urgings for investment in the radio in the 1920s.
■ Who the hell wants to hear actors talk? H.M. Warner, Warner Brothers, 1927.
■ But what is it good for? Engineer at the Advanced Computing Systems Division of IBM, 1968, commenting on the microchip.
■ There is no reason anyone would want a computer in their home. Ken Olson, president, chairman and founder of Digital Equipment Corporation, **1977!.**

■ Companies, like Benetton, Compaq, Matsushita, Motorola, Nissan, Toyota, and Tulip, consider Mass Customisation to be the key principle, in really satisfying customers. I expect that in 2005, many of these companies will be capable of fully mass customising products. After all, by then many of them will really be practising (and not being engaged into) the principle of Mass Customisation already for 15 years! Also, already 500 top companies of the world, have currently implemented SAP successfully. It can also be expected that many of *these* companies will be capable of mass customising products in 2005. If Philips really wants to make up their arrears, they will have to be demand activated in 2005 also. 5% of all entities will have been implemented already next year. These entities can start the move to Mass Customisation already in 1998. The following list shows the most important points in becoming DAMA:

- Dynamic market, applying proper quality, cost definitions.
  - Quality programs beyond ISO 9000 (e.g. exchange of engineers among companies).
  - Customer satisfaction is monitored, and the resulting conclusions are also applied into re-designs.
  - The entity where DAMA is going to be implemented, is accustomed to deal with considerable variety.
  - At the first entities to be implemented, market dynamics should not be too high.
- Products are 'DAMA-enabling'.
  - Products should be at least partly modular, but ideally 100%.
  - Product features are at least partly programmable, making modularity less essential.
  - Products have a platform design.
  - Products have open architectures.
- Short as well as long cyclic processes are customer oriented.
  - Feedback of end-user is used in adjusting product designs.
  - Customers are involved in the product creation process (e.g. Lead-Users).
- Flexible, slendered processes.
  - Principles of Lean Thinking are applied.
  - Wholesalers, dealers, plants are electronically integrated.
- Production allows for economies of scale and scope simultaneously.
  - Autonomous groups, no totally integrated processes (like light bulbs).
  - Machines allow for reasonably fast changeover.
  - Changeover reduction programs (e.g. SMED).
  - Processes are re-useable, commonality of processes.

- The way to becoming a mass customiser for Philips, consists of two main phases; implementing SAP (first), and implementing DAMA (second). To become a mass customiser as easy, fast as possible, the optimisation priority chosen of the steps to be made, should be attuned to these two phases *jointly*. Optimising the implementation time of the first phase separate from the next phase, would result into sub-optimisation of the total implementation efforts, see figure 6.3.

- This report is not aiming at being exhaustive. That would be like having stated the entire, perfected Mass Production system a hundred years ago, going much beyond the scope of this assignment. When talking about the principle of Mass Customisation, people look surprised. The principle of MC is to most people still unknown, even at the university, and at Philips. At the library of my faculty, I could only find a few books and articles dealing with the principle of MC. Of MP, there are hundreds. Therefore, this report just wants to indicate, when and why this largely unknown MC system can outperform traditional MP systems. It's also handing points of attention in becoming a mass customising company. Yet it remain just theories. Only practical experience will show the real value of these findings in mass customising products by Philips. At Philips, practising the principle of MC, could expose completely unexpected problems. Therefore, it's recommendable to start practising DAMA as fast as possible, in order to put Philips on the learning curve. But start implementing DAMA at the entities discussed is a very complex issue. It will possibly take much time, before Philips will (be able to) start implementing DAMA at these entities. Approvals are needed, and then SAP has to be implemented first.
In order to get onto the learning curve already now, Philips could start less complex DAMA projects. This could be done together with a partner. A service company, having those other competencies needed

when mass customising products, besides the mass producing ones. To this, the extended Telepost service has been proposed, which is possibly going to be executed. This is probably the best way to find out how Mass Customisation works. Trying it out, just like the companies mentioned in this report. But other DAMA cases should follow, and according to Pine below, almost everything is customisable.

> There are few products more complex than automobiles, and few processes, more complex than automobile manufacture. If automobiles can be mass-customised using bus modularity and all the other techniques, and there is little doubt they will be, most any product or service can also be mass-customised. (Pine [52]).

■ At first, only a few terminals will be needed for this Telepost proposal. But ultimately, these terminals could be placed at all possible places. And these terminals, pillars, could be applied for far more applications. Information pillars, placed at railway stations, or airports, could inform tourists, by showing the top 10 restaurants, or sightings, etc. The companies mentioned, will probably finance these pillars with great pleasure.
This report also mentioned companies using suchlike terminals, in creating cars, bicycles, glasses, etc. It can be expected that these terminals will increasingly appear in shops, and dealerships, especially those practising the principle of MC. So developing, and producing these now, even when only one or few, will put you on the learning curve of a product, possibly appearing everywhere in the (nearby?) future.

■ GSM is an example of a business where the offering of a service is far more important than the manufacturing and selling of the physical products. Real money appears to be made by offering services, instead of producing tangible products, for telephones are even given away for free. Requiring both mass producing competencies, as well as flexible, service offering competencies, in order to be capable of serving customers entirely. It appears to me that Philips wishes to make money by trying to serve the end-user. Yet without having all the essential competencies to do so. That appears to be at least questionable. It would be preferable to implement the DAMA capabilities to do so. To try to obtain all competencies needed for serving the end-user properly. But if not possible (yet), the next best solution is probably to look for a partner, as in the Telepost proposal. Then, Philips can focus onto the level below. The supply of parts of the desired system, like telephones and power supplies, to their partner having the capability of serving the end-user entirely. Thus in stead of serving end-users, producing large volumes of telephones for a telephone company, having the capabilities of serving that end-user properly.

■ By making specific attributes of products programmable, the ability of customisation appears to increase enormously, simultaneously decreasing the costs of customisation. Just look again at the difference in prices, and capabilities between the old type-writers, and today's wordprocessors! So, especially when producing huge amounts of the same products, like many parts of Philips, software could be an excellent tool in differentiating those mass produced products, also from those produced by rivals! Expressing the value for Philips to get more involved in software.

■ In gathering information for this graduate assignment, the most essential information, or important references have been found at the Internet. To me, it proved to be the most up-to-date, and inexhaustible source of really all kinds of information. Despite the current lack of speed of the Internet, it offers enormous opportunities. But when studying at the university, the opportunities of the Internet were still unfamiliar to me. It would be recommendable to show students the fantastic things that Internet can do for them, already in the first year. The Internet facilities could also be integrated within some subjects. It would be recommendable also, to make it a habit to consult the Internet all along Philips, in finding answers to all kinds of problems, and for free! This before starting costly researches, possibly eliminating reinventing solutions already obtained by others.

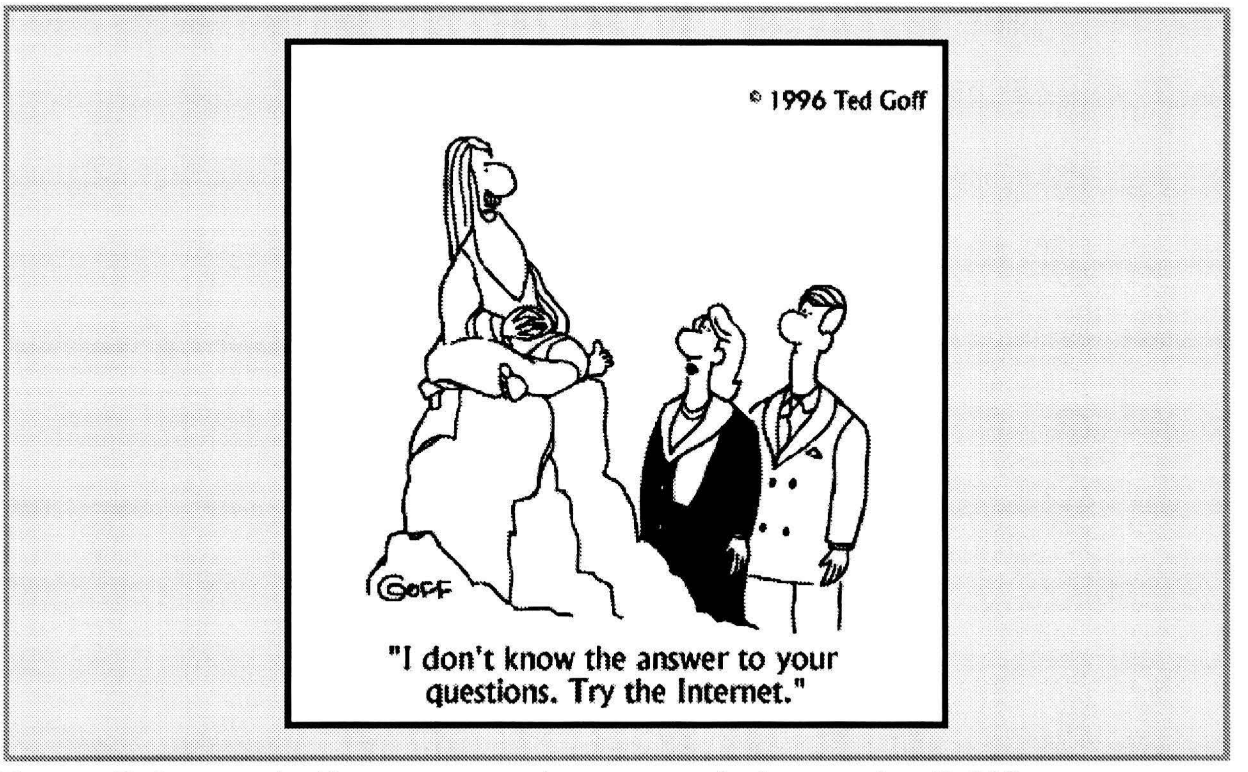


Figure 7.1: The Internet as the ultimate guru, a source for answers to truly *all* your questions. (Goff [c]).

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Annexes

Annex 1: Case: Caterpillar makes decisions in the virtual world, sees the benefits in the real world.
Annex 2: Case: Imax gets the big picture with Virtual Prototyping.
Annex 3: Case: Benetton formula merges engineering speed and Grand Prix performance.
Annex 4: Letter Doug Dunn.

Annex 1 Case: Caterpillar makes decisions in the virtual world, sees the benefits in the real world.

Caterpillar, the world-wide manufacturer of tractors, loaders, and other off-highway equipment, faced a challenge familiar to almost any manufacturer in today's business environment. To improve profitability, the company needed to reduce its operating expenses. Meanwhile, global competition was raising its customers' expectations for product performance. As a result, Caterpillar faced the dual challenges of cutting design and manufacturing costs, while simultaneously improving the already high standards of quality in its product line.

Caterpillar's engineers faced a big obstacle to these goals. To build even a single hardware prototype of any of its larger machines typically required weeks or even months to complete and cost millions of dollars. If design changes dictated additional hardware prototypes, the time and cost of development simply multiplied.

Caterpillar's approach was to fundamentally change its design and testing processes. Caterpillar envisioned a way to gain both time and cost advantages in product development, while simultaneously optimising the quality of its product designs. Caterpillar wanted to give its engineers the ability to quickly test hundreds or even thousands of design variations on the computer before ever cutting a piece of metal.

Virtual Prototyping has given Caterpillar these capabilities. Not only are they now reducing design costs and getting their products to market faster, they're building better products. Products that get their customers excited.

As an example, consider a large front-end loader used in mining operations. The bucket of a Caterpillar 992D used in large open pit mines can hold a 45,000 pound load. If the unit is standing still, an engineer can estimate the forces on a component of the bucket linkage with a reasonable degree of accuracy. But what if the loader is moving while raising the bucket and at the same time one wheel drops into a large hole? This could dramatically change the magnitude and direction of the forces on that part.

Traditional product development methods would require that a prototype be fabricated and then tested under a wide range of loading conditions. For a large piece of equipment, this can cost hundreds of thousands of dollars and take many months. If there is a failure during testing, the parts need to be redesigned and a new prototype built. Then the test cycle is repeated. In many cases, the process is repeated over and over because the cause of the failure is not obvious. One result is that engineers will over-design components since they are unsure that all operational conditions will be adequately tested.

With the help of Virtual Prototyping, Caterpillar's engineers are greatly extending the limits of their design capabilities. It's now much easier for them to evaluate designs from the user's perspective. They're eliminating field testing until they're close to an optimal design. And in the most basic and important sense, Virtual Prototyping is helping Caterpillar do a much better job of innovating.

(Frostbyte Communications Inc., 1995 [k]).

Annex 2 Case: Imax gets the big picture with Virtual Prototyping.

As anyone who has visited Epcot or one of 125 other specially equipped theatres throughout the world will attest, the Imax movie experience is unlike any other. Whether the film is on nature, space exploration, or a Rolling Stones' concert, the Imax system produces a motion picture image of unsurpassed size, clarity, and impact projected onto a screen up to eight stories high and extending beyond the viewer's range of peripheral vision. The complex camera, projectors, and accessories used by Imax Corporation of Ontario, Canada, to create their giant-screen movies are so specialised they must be custom-designed by the company.
Imax uses some of the most advanced equipment in the motion picture industry to precisely control a steady feed of film critical to the clarity characteristic of its images. Cameras have a specially designed internal mechanism to handle film that is three times larger than professional 70 mm frame.
Projectors use a rolling loop movement that advances film in a smooth wave-like motion at up to 48 frames per second. Frames are individually positioned by fixed registration pins and held in place by a vacuum system. Imax systems have a variety of support equipment and accessories such as reel units that move film in and out of the projector.

"None of this is available off-the-shelf," explains Mehran Omidvar, Imax mechanical design engineering specialist. "We have to custom design everything to accommodate the larger film format. Tolerances are very tight, with accuracy's of 10 millionths of an inch in certain areas. With images projected so big on the screen, we absolutely need smooth motion, with no jitters or vibration. The audience would see this right away, and the illusion of being part of the action would be lost."

Historically, Imax engineers used hand calculations to design this precision equipment, and built physical prototypes to verify its designs. But assemblies often failed perform as required, forcing the engineering team to modify its designs, build new prototypes, and physically retest again and again. As a result, each major new piece of equipment generally took years to develop.
To eliminate delays in product development, Imax turned to Virtual Prototyping based on ADAMS software, the flagship product of Mechanical Dynamics Inc. of Ann Arbor, MI. Imax licensed ADAMS in July 1994 and immediately began using it to develop the main film mechanism for a new camera. The mechanism is a complex assembly of many precision parts, all of which must work flawlessly together to create high-quality motion pictures.

The first step for Omidvar was to roughly sketch his idea for the mechanism on a piece of paper. He then used that initial geometry as a basis for constructing a model, complete with joints, constraints, and motion generators. This model was then animated to verify the basic movement of the assembly through its entire range of motion. This kinematic simulation determined linkage displacements, velocities, and accelerations and allowed him to locate lock-up positions, spot interference's, and define motion envelopes.
One of the key features of this tool is that the user can readily modify the geometry of the mechanism by modifying any parameter and rerunning the simulation until it delivers the required motion.

Next, the mechanism geometry was transferred to AutoCAD to model the individual components as solid models. AutoCAD determined the components' mass properties, and the information was entered into the model. A dynamic analysis run on the model then determined forces in the various linkages and joints.
Force data was entered into the ANSYS finite-element package from ANSYS Inc. to determine stresses and deformation in the various parts. Geometry of components in the CAD model was then modified to

reduce high stresses and lower deformations that were too great, and the simulation were rerun until the parameters were within acceptable limits.
"It is a circle that goes around until you are happy with it," explains Omidvar. "Virtual Prototyping gives us the luxury of going through many different mechanisms. Done manually, the work we did on the camera would have taken years. We completed the design in only a few months."

Because of the savings obtained in using Virtual Prototyping tools to help design their camera, the company expects to use the software on many other future projects including cameras, projectors, and accessories.

(Chilton Company, Inc., April 1996 [i]).

Annex 3 Case: Benetton formula merges engineering speed and Grand Prix performance.

Benetton Formula Ltd., winner of the Formula One World Driver's Championship in 1994, has invested substantially in developing an effective and efficient IT infrastructure, based around HP's Empowered Engineering strategy. But, they wanted to improve information flow still further within the organisation by implementing multimedia communication tools.
HP's multimedia tools facilitated effective collaboration among engineers working at a number of diverse locations. The locations include Benetton's technical centre in Oxford, a wind tunnel in Farnborough, a permanent test facility at Silverstone, and race and test circuits world-wide. And until recently, information exchange among the sites relied primarily on phone and fax. However, the limitations of these methods have been brought into focus by an ever-increasing need for rapid design and modification work.

"Grand Prix races are only two weeks apart, and we have come to realise that every hour counts if we are to make the most of this time to carry out modifications and improvements. With our people often scattered over several different sites or in transit between race track and factory, we need to implement the most advanced collaborative communication technology available," said Fred Mundle, IT manager at Benetton Formula's technical centre.
"Whilst we were a bit sceptical at first about the value of tools such as multimedia mail and shared whiteboards in an intimate environment such as ours, when we sat down to analyse exactly how we work and how often people are on the move, then we had no doubts about their relevance," he continued.

Collaborative projects:
The establishment of new communication links at Benetton was addressed throughout 1995 by participating in several collaborative projects with HP. To support collaborative multimedia communication among the sites, ISDN connectivity was implemented with ISDN links established between the technical centre, the wind tunnel and Silverstone, with other race circuits to follow.
At the wind tunnel in Farnborough, each HP workstation can now be connected to four ISDN lines, allowing data to be exchanged with the technical centre at a rate of 30 kilobytes per second. "Even without collaborative multimedia, engineers working at the wind tunnel were reporting benefits from ISDN connection. They can link up with the engineering database and work in wireframe, just as though they were sitting at a workstation back in the technical centre," said Mundle.
However, there is no doubt in Mundle's mind that the most significant benefits of the new ISDN links are associated with their support for collaborative multimedia communication.

The first collaborative multimedia project involves implementation of UNIX multimedia mail with HP's collaborative multimedia suite, MPower 2.0, which supports communication through voice, images and text. Following a successful pilot within the aerodynamics group, multimedia mail is now implemented on all workstations, with extension to PCs by the end of 1995. The aim is to achieve closer linkage among the teams involved in engineering, manufacturing, performance testing and racing.

The second project aimed to implement 'whiteboard' communications using HP Shared X, to enable collaborative working. Shared X technology allows any X11-based application to be displayed on multiple workstations, with each user in the session able to contribute. A pilot within the aerodynamics group at Benetton was followed by more widespread implementation throughout the organisation.
It is also anticipated that HP Shared X will be used to exchange CAD designs more widely, particularly with external suppliers and with Renault.

The third collaborative multimedia project involved implementation of video communications to enable real-time video capture and electronic transmission. This allows information to be exchanged in useful and timely form among the engineers working at different sites. Video-conferencing alone is not appropriate for Benetton's purposes, as it cannot capture real-time data.

Benetton has now installed video technology at the wind tunnel and the test circuit at Silverstone. Using the multimedia mail facility, video sequences are being transmitted to the technical centre via ISDN links.

Following the overwhelming success of the pilot tests, collaborative multimedia communication is now starting to be used in a variety of practical situations. For example, a combination of multimedia mail, Shared X and video is being used for communication between race engineers carrying out tests at Silverstone and their counterparts back at the technical centre in Oxford.

When engineering problems are encountered at the circuit, video sequences of the relevant components are taken, three-dimensional information being conveyed by rotating the components in front of the camera. The video sequences are then sent electronically to the technical centre using HP MPower. Subsequently, individual frames can be incorporated into collaborative Shared X sessions. Multimedia mail is also used to send CAD drawings from the technical centre to the circuit. These drawings can then be discussed and annotated by all interested parties using HP Shared X.

A similar sequence of events takes place at the wind tunnel, with video clips of the behaviour of the wind tunnel model being transmitted back to Oxford by multimedia mail. Again, CAD drawings can be discussed and annotated using Shared X, and changes made to the wind tunnel model can be incorporated into the design.

Recently, three-way collaborative meetings between wind tunnel, test circuit and technical centre have been instigated. In this way, aerodynamic work at the wind tunnel can run in parallel with testing at Silverstone, with engineers at Oxford also having an input.

"Now that we have our ISDN links in place and our collaborative multimedia tools up and running, we are beginning to experience some significant time savings. Previously, the wind tunnel and the factory would have communicated by fax, with lengthy telephone conversations to follow up, and quite often a full exchange of ideas would have to wait until somebody made the 100km journey to the factory. Now, we can reach a shared level of understanding much more quickly, especially when video sequences are used," said Mundle.

The HP MPower software used for multimedia mail also supports faxing and scanning of documents. This means that output from a shared whiteboard session, in the form of an annotated CAD drawing and video image, for example, can be faxed directly to one of Benetton's suppliers. "Within minutes of deciding that we need to communicate something to a supplier, all the necessary information can be in the supplier's office. The next step in the process will be to implement ISDN links with some of these suppliers, making information exchange even more efficient," commented Mundle.

Although the most obvious benefits of the new collaborative tools relate to communication among the sites, they are also having an effect at the technical centre. According to Mundle, this is because different people's working hours often do not coincide, despite the fact that most of Benetton's engineering work is now concentrated at this centre.

"To make maximum use of the time available, we keep the centre open 24 hours a day, and people come and go at all times including weekends, with particularly unusual working hours immediately before or after a race. So the opportunities for face-to-face contact with one's colleagues are less than they might seem," explained Mundle.

Because of this, Benetton's people are beginning to use multimedia mail to leave messages for one another in the form of video sequences, images or annotated CAD drawings: This, claims Mundle, is allowing them to communicate in a much more versatile way than before.

HP believes that the most important aspect of its Empowered Engineering strategy is the capacity for enterprise-wide team communication and collaboration. Without this capacity, the slowness and inefficiency of information exchange will always limit a company's capacity to reduce time-to-market by implementing Concurrent Engineering.
In Benetton Formula's case, the need for effective communication is accentuated by the exceptional time constraints under which its engineers have to operate. However, by working with HP to implement Empowered Engineering, Benetton has put in place an infrastructure which is meeting all its communication needs.
"We think we've already got the best IT infrastructure in Formula One, by a long way. But in order to position the team to win in the future, we are having to work with HP to improve our communication processes still further. Collaborative multimedia communication is a new area for us, but from what we've seen so far, we believe that it will give us a significant competitive advantage," concluded Mundle.

(Hewlett Packard, March 8, 1996 [e]).

Annex 4 Letter Doug Dunn.

Thursday July 25, 1996 the Board Of Management of Philips revealed, in the context of the announcement of the financial results over the second quarter 1996 that developments in the industry and the markets of Consumer Electronics require a structural realignment of the Philips Sound & Vision activities.

Despite the joint efforts of all of us, the financial results of Philips Sound & Vision are still disappointing. Against this background the management of Sound & Vision has decided to embark on a major profit improvement programme. This programme will:

- improve substantial the financial results of our current products.
- as well divert more resources to the creation and marketing of new digital applications.

This profit improvement programme has to result in a substantial reduction of the operational cost and cost of materials. This objective can only be realised by a fundamental change of the ways of working in the total business chain from supplier to customer.
These different ways of working relate amongst other things to:

- work with global product concepts for the development of products.
- that are produced with standardised manufacturing processes.
- in which, as much as possible, standard components are used which are purchased from a restricted number of selected suppliers.
- which also has to result in a considerable increase of the manufacturing flexibility and the delivery reliability of the factories.
- this to be supported by globally standardised logistic operations and Information Technology systems.
- together with a better interlinkage of the marketing function with the industry.
- and a sustainable reduction of the selling expenses.

Apart from above mentioned actions, profit improvement has to be realised by developing, producing and selling of new products for the consumer.

The profit improvement programme is directed at all activities in Sound & Vision world wide: development, production, marketing, sales and support activities. This will cause a headcount reduction of at least 6,000 persons world-wide (or 15%) before end 1997. Therefore, an extraordinary pre-tax charge of NLG 800 mln has been recognised in the second quarter.

The preparation of the above mentioned action plan is in progress. As soon as, in the coming months, the preparations are concluded, discussions will take place with the respective management and employees.

The realisation of the above mentioned objectives will ask a great effort from all of us. I am personally convinced that we need to take these severe measures in order to secure a sustainable positive result in our business.

D.J. Dunn
CEO Sound & Vision

(FIL Supply Chain Management [49]).