Paul Edegger, BA

Technical and Economical Feasibility Study of the Application of Shape Memory Materials in Car Seats

Diploma Thesis

Mechanical Engineering and Business Economics
Production Science and Management

Graz University of Technology
Faculty of Mechanical Engineering and Economic Sciences

Institute of Industrial Management and Innovation Research
Univ.-Prof. Dipl.-Ing. Dr.techn. Christian Ramsauer

Graz, June 2013

Statutory Declaration

I declare that I have written this thesis independently, that I have not used other than the declared sources / resources and that I have explicitly marked all material which has been quoted either literally or by content from the used sources.

Graz, ……………………………   ………………………………

(Signature)

Acknowledgement

I would like to sincerely thank Magna International Europe and the Department of Cooperate Engineering and R&D for the opportunity to write my thesis in cooperation with an international company and thus gain valuable experience for my future career.

Furthermore, I would like to thank my team-mates from the Department of Corporate Engineering and R&D, Ines Kähsmayer and Claus Breitfuss, Reinhard Brandstätter from Burg Design, and Vladan Stevanovic for their active support, the very friendly and easy working environment and their dedicated cooperation.

My thanks go also to Univ.-Prof. Dipl.-Ing. Dr.techn. Christian Ramsauer, head of the department for Industrial Management and Innovation Research and to my supervisor Mario Kleindienst who advised and supported me throughout the course of my thesis.

I thank my parents who supported me, not only while writing my diploma thesis but also during my entire studies.

Last but not least I want to say thank you to my girlfriend Irene, who knew better than anyone else how to motivate me.

Abstract

This diploma thesis, entitled *“Technical and Economical Feasibility Study of the Application of Shape Memory Alloys in Car Seats”,* deals with a proposal for an innovative product. This proposal arose from a program called WIN - Winning Innovations, which was instituted with the aim to promote innovation within Magna.

Magna has the intention to use the special properties of Shape Memory Alloys in car adjustment systems. Shape Memory Alloys, when treated in the right way, change their shape on demand, even under high load. The shape changing effect reacts to temperature changes but can also be triggered by electricity. The application of these alloys makes the realisation of targeted longitudinal movement and torsion possible. Thus, it enables the substitution of traditional adjustment systems using gears and motors or other actuator systems.

The aim of this work is the review of the economic feasibility of the product idea. In this context, attention is drawn to the possible risks and hazards and also to possibilities and opportunities that could arise in the course of a product realisation.

The theoretical part of the thesis deals with the basics of operational innovation and shape memory materials in order to provide the reader with background knowledge and facilitate the understanding of the practical part.

The main parts of the practical work are the feasibility study and the derived business plan, which have the aim of supporting the management of Magna International Incorporated regarding the decision for a realisation of the product idea. Furthermore, the business plan points out the benefits of the product innovation, show the future market and revenue potential, focus on potential partners and competitors and discuss the financing of the product development.

Kurzfassung

Die vorliegende Diplomarbeit mit dem Titel „*Technical and Economical Feasibility Study of the Application of Shape Memory Alloys in Car Seats”* befasst sich mit einem Vorschlag für eine Produktinnovation der im Rahmen des Programms mit dem Namen WIN – Winning Innovations, ein Programm zur Stärkung von Magna's Innovationskraft, endstanden ist.

Magna hat die Absicht, die besonderen Eigenschaften von Formgedächtnislegierungen für Verstellmechanismen im Auto und im speziellen für Autositze anzuwenden. Formgedächtnislegierungen sind in der Lage ihre Form, selbst unter Einwirkung hoher Kräfte gezielt zu verändern. Dieser Formgedächtniseffekt reagiert nicht nur auf Temperaturänderungen, sondern kann auch mit Hilfe elektrischen Stroms angesteuert werden. Die Anwendung dieser Legierung ermöglicht die Realisierung von gezielter Längsbewegung oder Torsion und damit die Substitution von traditionellen Systemen.

Das Ziel der Arbeit ist die Überprüfung der Wirtschaftlichkeit der Produktidee. In diesem Zusammenhang wird auf mögliche Risiken und Gefahren, aber auch auf Möglichkeiten und Chancen hingewiesen, die im Zuge einer Produktrealisierung entstehen können.

Der Theoretische Teil der Arbeit befasst sich mit Grundlagen zu den Themenschwerpunkten „Betriebliche Innovation“ und „Formgedächtnismaterialien“ um dem Leser das Verstehen des praktischen Teils zu erleichtern.

Den Hauptteil der praktischen Arbeit bilden die Machbarkeitsstudie und der davon abgeleitete Businessplan, mit dem Ziel, das Management von Magna International Incorporated bei der Realisierung der Produktidee zu unterstützen. Der Business Plan zeigt des Weiteren den Nutzen der Produktinnovation auf, stellt das Marktpotential und mögliche Gewinne dar, geht auf mögliche Kooperationspartner und Wettbewerber ein und thematisiert die Finanzierung der Entwicklung.

Table of contents

1 Introduction

The diploma thesis at hand deals with an innovation project launched by Magna International and Magna Seating. With a feasibility study and the derived business plan, it should be identified in advance, whether it makes sense to use the product idea commercially or not. The work serves as a decision aid for the management of Magna but also for Magna groups that will work with this innovative idea in the future. Chapter one describes the initial situation and the objectives pursued by this work as well as the procedure in order to achieve the set objectives.

1.1 Initial Situation

An innovative idea with the name “Mechatronic Adjustment System Automotive (MASA) has arisen in 2012 in the context of a special idea generation program, created by Magna. To give the reader a general overview of the initial situation, the company but also the Department of Corporate Engineering and R&D will be presented. The idea, which is this thesis about, is described at the beginning of the practical part in chapter four.

1.1.1 Magna International Incorporated

Magna has its roots in the tool and die company Multimatic Investments Limited, founded by Frank Stronach in 1957. Later, this company took up the production of car parts and in 1969, merged with Magna Electronics Corporation Limited to form the company Magna International Inc. In 1988, Frank Stronach launched the so-called Employee Charter, which is the framework for business principles and the guide for the corporate culture of Magna International Inc. The Charter includes a profit sharing key for management, employees, shareholders and the public. Furthermore, it means that the company is obliged to give a percentage of profits to charity and non-profit organisations (Magna International Inc. Website, 19.4.2013).

Today, Magna supplies basically every car manufacturer in the world and employs, as illustrated in Figure 1.1, over 121.000 workers, in over 400 production, engineering, and Research and Development (R&D) centres in 29 countries, on five continents (Magna International Inc. Website, 19.4.2013).

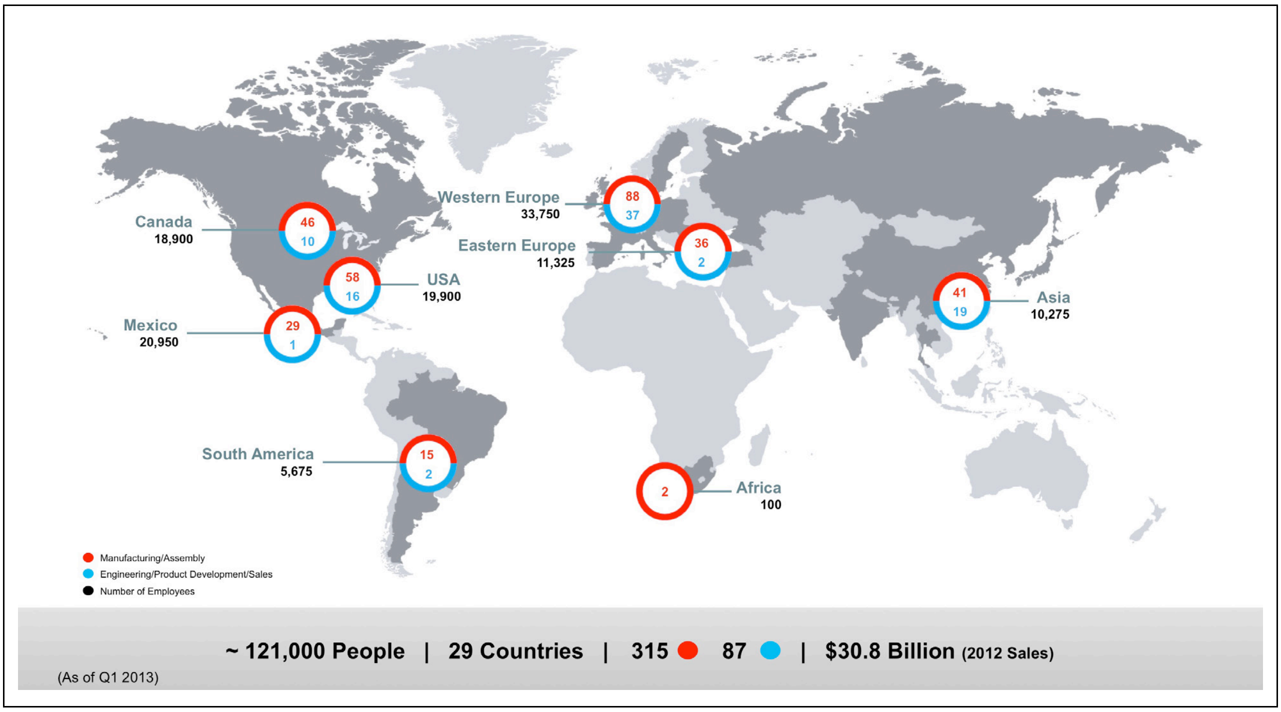

Figure 1.1: Global situation of magna (Magna International Inc. Website, 8.7.2013)

Magna describes itself as the world's most diversified automotive supplier. In addition to the design and manufacturing of automotive systems, assemblies and modules, Magna designs and assembles complete vehicles. Magna sells primarily to original equipment manufacturers (OEM) of light vehicles and trucks in three geographic segments: North America, Europe, and the rest of the world (primarily Asia, South America and Africa). Characteristic of Magna is the segregation into individual production and development divisions, which represent autonomous business units. Figure 1.2 shows Magna's corporate structure (Magna International Inc. Website, 19.4.2013).

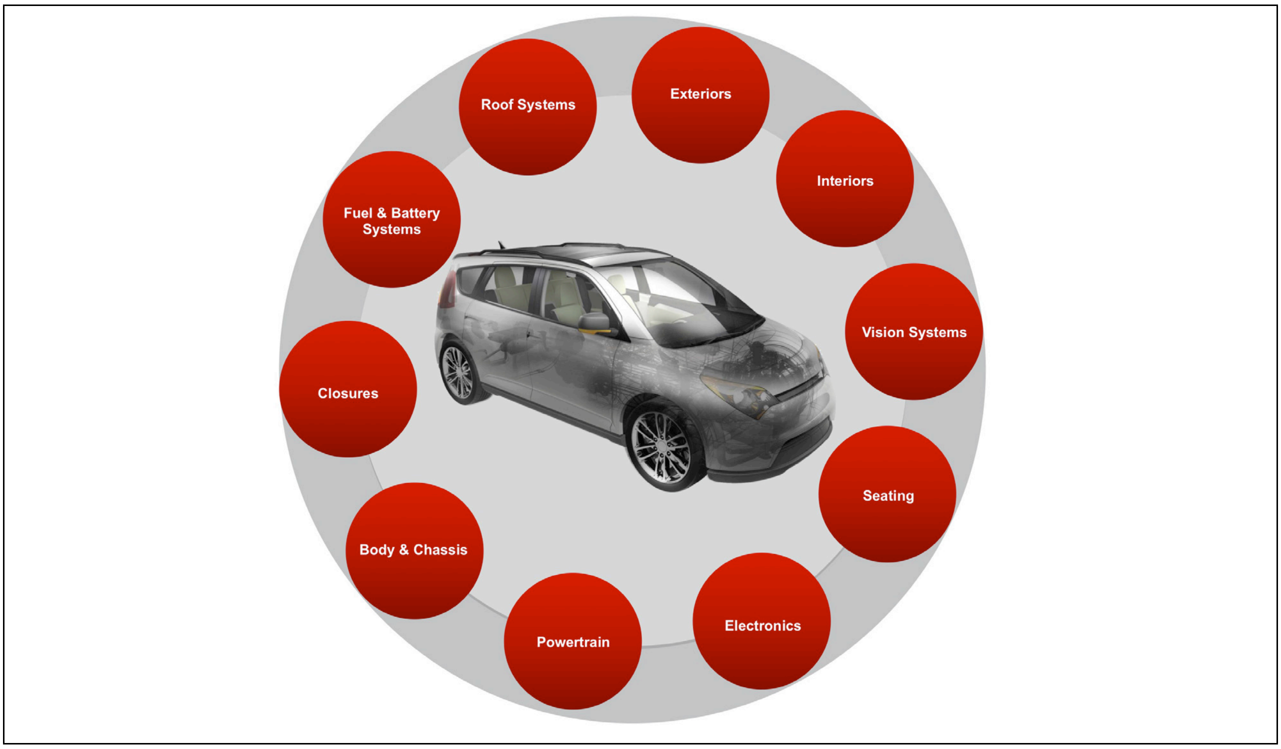

Figure 1.2: Corporate structure of Magna (Magna International Inc. Website, 8.6.2013)

1.1.2 Department of Corporate Engineering and R&D

The Department of Corporate Engineering and R&D cannot be assigned to a division but acts in a pluridisciplinary way. Its main task is to promote and enhance innovation within the entire Magna group. In this regard, a program called WIN (Winning Innovations) is run to promote innovation. WIN fosters employees to create ideas for new products, processes and technologies (Magna International Inc. Website, 19.4.2013).

Since good ideas cannot only come from the department of R&D, this program aims to reach all kinds of Magna employees and tries to encourage them to think about new solutions to problems. The ideas can be submitted at any time, via e-mail or by post. After a pre-filtering for certain exclusion criteria, the remaining ideas are evaluated by a committee. Each year, ten ideas are selected and subsequently developed by external institutions, universities or Magna itself (Winning Innovations Website, 20.4. 2013). This work examines an idea generated as a result of the WIN program in 2012.

1.2 Objectives

The aim of this work is to examine the technical and economic potential of a WIN Idea with the name Mechatronic Adjustment System Automotive (MASA). It is planned to replace traditional actuator systems with the new technology in order to reduce noise, space consumption, weight and costs. The innovation is to use special alloys that are capable of changing the shape when demanded. A feasibility study is conducted under the application of analysis and techniques that have been proven to investigate product innovations. In addition to the development process, the work aims to point out possible future applications, as well as strengths and weaknesses. All findings will be summarised in a final business plan that serves as support in decision making for key management.

In addition to the practical part, the work aims to provide the reader with theoretical principles in the areas of operational innovation and shape memory materials in order for the results to be interpreted to the full extent.

1.3 Approach

The first chapter describes the company Magna International Inc., the Department of Corporate Engineering and R&D with the embedded initiative Winning Innovations and finally, discusses the objectives and the approach of this work.

Chapter two deals with the theoretical background regarding the innovation process. The term ‘innovation’ has to be defined and differentiated from others to guarantee a uniform way of looking at things. In addition to this, the innovation management, innovation strategy and innovation process need to be described in a detailed way, including a definition and description of innovation phases and tools.

The special structure and different types of Shape Memory Alloys (SMA) need to be explained and distinguished to provide a basic understanding of their behaviour, since SMA are the core elements of the innovative idea.

Chapter four screens and evaluates the idea from both a technical and economical point of view, using the presented tools and techniques suitable for each particular phase. The core of the practical part is the feasibility study, with the aim of creating a base for further decisions on the development of the project. Subsequently, a business plan is derived from the findings of the feasibility study.

The last step forms a summary of the diploma thesis including a critical reflection of results. Furthermore, recommendations for future decisions have to be made.

2 Innovation and management of innovation

This chapter provides the reader with a theoretical background on innovation and management of innovation. Furthermore it differentiates the concept of innovation.

2.1 Concept of innovation

A clear delineation of concepts is necessary, since Innovation is complex and has a lot of different manifestations. Thus, different types of innovations with different characteristics exist and need to be described. Furthermore, the chapter presents aims, factors for failure and success as well as driving forces and impediments of innovations.

2.1.1 Disambiguation

This part of chapter two will clearly distinguish the terms innovation, invention, imitation and modification to create a common base of interpretation.

Innovation

The term innovation has its origin in the Latin word “novus” = new and “innovare” = renovate. The combination of these two words led to “innovatio” = innovation as we know it nowadays (Horsch 2003, p. 1). Drucker (2007, ch. 2) defines innovation as follows:

> *‘Innovation is the specific instrument of entrepreneurship. It is the act that endows recourses with a new capacity to create wealth.’*

Defining the word ‘innovation’ in a uniform way causes problems. Many definitions can be found in books but a generally valid definition does not exist. Schumpeter (1952, p. 100) remarked at the beginning of the 20th Century that innovation is the enforcement of new combinations of existing things and forces. According to Schumpeter include Innovations new products, processes, the opening up of new markets and new organisations. Hauschild (1993, pp. 5-7) states that products and processes are subjects of innovation of market economy. Therefore, the in-house use of processes and the economic use of products is crucial for innovations. Furthermore, he revealed that the combination of novelty and change are common characteristics of all definitions. Innovation is therefore connected with problem solving processes.

The term ‘novelty’ also requires further definition. What is new for whom? The view of an expert may be different to the view of a consumer. Within a company, different interpretations of innovation exist between the management and workers (Trott 2005, p. 5). Hauschild (1993, pp. 13-16) highlights the importance of an internal definition of what innovation is for the company, and suggests to name those products and processes that appear for the first time in a certain enterprise as innovative. Horsch (2003 p. 10) adds that an innovation does not have to be radically new. As stated above, novelty is subjective and differs from person to person and from company to company. Anyway, even innovation projects with a very high degree of novelty have similarities to former projects.

Invention

First of all, it is necessary to state that, as is often assumed, an invention is not the initial step of an innovation. In simple terms, to start with, an idea arises from a certain need. If the realisation of this idea requires additional knowledge, a project is usually the consequence. The project represents the organisational frame of knowledge creation. The successful conclusion of such a project can lead to an invention (Brockhoff 1992, p. 27).

An invention is therefore the fixing of a certain alternative with defined characteristics and detailed descriptions of properties (Hauschild 1993, p. 19). It has to enrich the state of the art in a way that a patent registration is possible (Wohinz 1983, p. 24).

The term ‘invention’ can now be clearly distinguished from the very similar word ‘innovation’. Invention is just one step in an innovation process. To achieve an innovation certain steps have to be taken. Literature recognises that such an innovation process includes at least the following steps: new idea, observation, investigation, development, invention and launch (Hauschild 1993, pp. 16-19).

Imitation

An imitation is the copy of something already existing. This can be a product or a successful process of another company. In principle, the term ‘imitation’ carries negative connotations (Vahs & Burmester 1999, p. 79). Wohinz (1983, p. 24) affirms that imitations are based on already existing products on the market. If companies can apply innovations of others to own products and are able to eliminate weak spots of the original innovation, they can achieve high economic success. He calls this “innovative imitation”.

Hauschild (1993, pp. 46-47) states that even though imitations have a bad reputation, it is not improper to imitate if innovations of others are not sufficiently protected. This is often the case because many companies do not deliberately protect their innovations. In addition, Horsch (2003, p. 7) points out, that imitation of a process or a product can again be seen as an innovation of the imitating company.

Figure 2.1 illustrates the dependencies of the terms discussed in chapter 2.1.1 The term 'diffusion' represents hereby the time and area dependent extension of a product on a market. (Horsch 2003, p. 6)

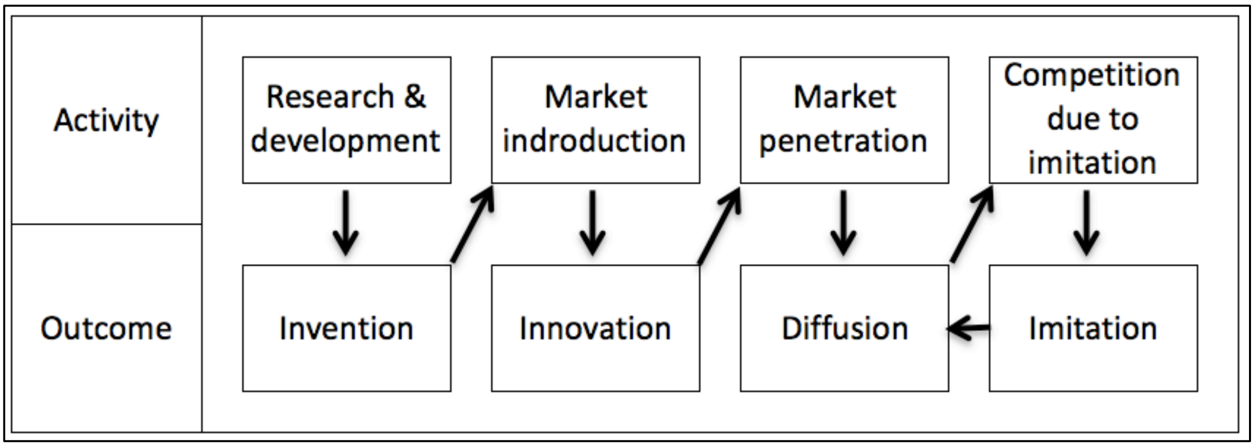

Figure 2.1: Dependencies of Invention Innovation Diffusion and Imitation (Brockhoff 1992, p. 30)

Modification

Seibert (1998, p. 110) defines a product modification[1] as a change of already launched products to improve them, adapt them to a new market situation or to reduce the costs. This can be realised by changing the styling, rearranging the components, applying more efficient processes or adding new functions to the former product. He sees it as an innovation with a very low degree of novelty in both areas, within the company and on the market.

Product modification is a measure that cannot be distinguished clearly from measures like product differentiation or product care, which are no longer ranged among product innovation activities. Nevertheless, the basic approach and used tools of such modification projects are very similar to innovation projects (Meffert 1998, pp. 423-424).

2.1.2 Types of innovations

In daily life, the term innovation is often automatically associated with a new product but innovations can also be new services, processes, structures, markets, and cultures. Therefore, Disselkamp (2012, p. 21) distinguishes between the innovation types illustrated in Figure 2.2.

[1] Due to the fact that this work deals with a product innovation, the term product modification and not the overall term modification is defined.

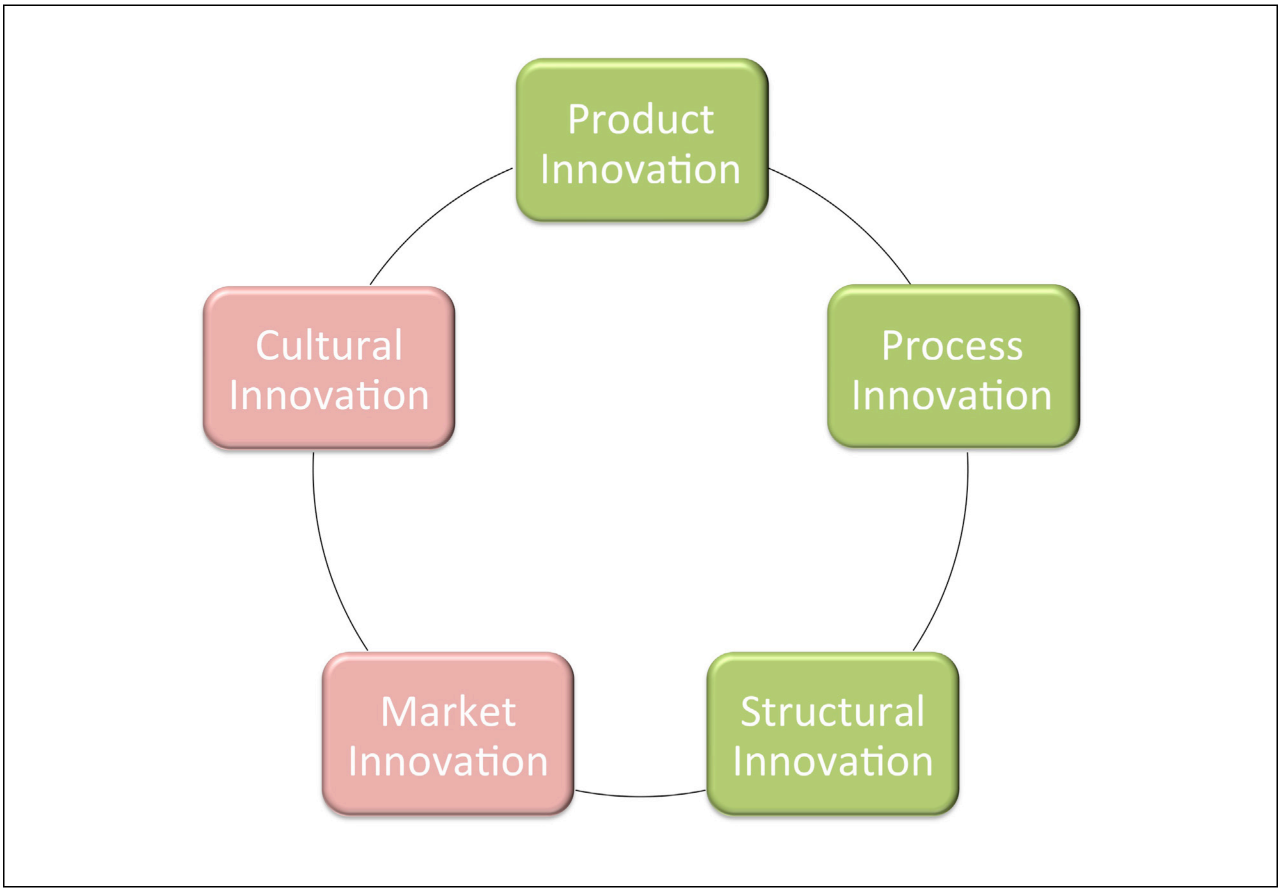

Figure 2.2: Types of innovation (Disselkamp 2012, p. 21)

For the sake of completeness, it should be noted that literature provides many other models. However, mostly just product, process and structural innovations are mentioned as considerable types. The term cultural innovation can also be replaced by social innovation (Vahs & Burmester 1999, pp. 73-78; Disselkamp 2012, pp. 21-29).

Product innovation

Product innovations are either new and currently unavailable products or significantly improved and already existing products. They show new, useful properties and a higher benefit for customers in comparison to former and similar products (Sabisch 1991, p. 64).

Product innovations lead to new goods or services that can be placed either on an already existing or a new market. Figure 2.3 shows the position of product innovations and other typical product development strategies regarding the market orientation and the degree of novelty (Disselkamp 2012, p. 21).

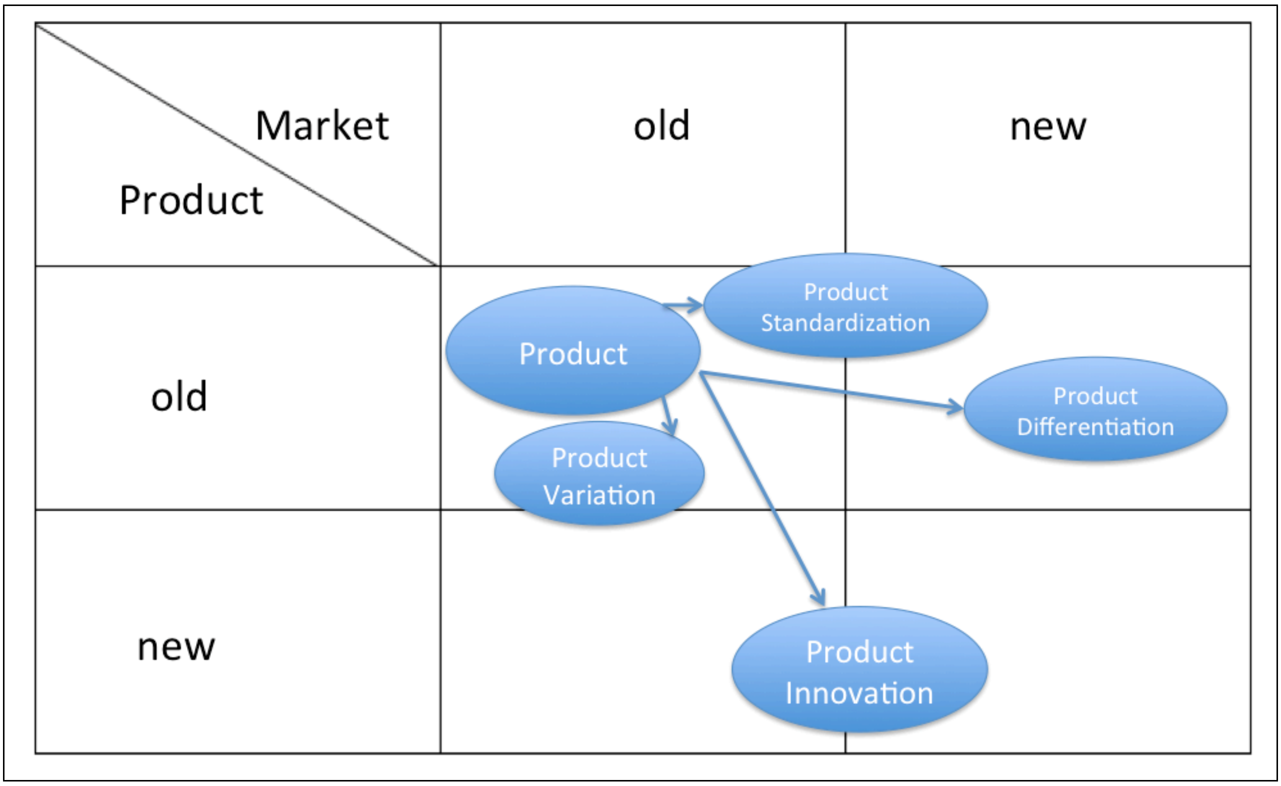

Figure 2.3: Directions of product development (Disselkamp 2012, p. 21)

As stated above, product innovations are significantly new products and services on a known or completely new market. However, it is difficult to define what exactly is significantly new. The age of a product is not decisive in the sense of 'new' but the new benefit it brings for a certain user group is. User groups are not just customers but also production and sales departments, which can also benefit from a product innovation (Disselkamp 2012, pp. 22-23).

The benefit for goods and services is always the prime factor in relation to customer purchasing decisions. For goods, shape, colour, and volume are also important, whereas for services, quality assurance and flexibility are dominant factors (Disselkamp 2012, p. 23).

Process Innovation

Product innovations are related to the output or result of operational processes. Process innovations in turn are the improvement of exactly these operational processes. A product innovation is usually combined with a process innovation, but process innovations do not imply inevitable product innovations. A new and innovative process, for example, can also lead to a lower price of an already existing product (Thom 1980, p. 36).

Nevertheless, exist between product and process innovations connections that extend beyond company boarders. Due to these dependencies, high quality processes are imperative for achieving high product quality (Trommsdorff & Steinhoff 2007, pp. 27-28).

Process innovations are task oriented and try to eliminate weaknesses of processes to reach better properties. They aim to enhance safety, increase productivity or customer satisfaction and to be environmentally friendly. Process innovations do not just take place within a company but can also be cooperation projects between several companies. Also, other branches and industry sectors can adopt processes and develop them further (Disselkamp 2012, p. 24).

Structural innovation

Structural innovations attempt to improve operational and organisational structures. In most cases they are closely related to process, product and social innovations. Vahs & Burmester (1999, p. 77) distinguish between hard and soft goals regarding structural innovations. Hard goals are, for example, the reduction of costs, improvement of quality and increase in productivity, whereas soft goals aim to improve, for instance, job satisfaction or work atmosphere.

Furthermore, structural innovation can contribute to employee motivation and qualification as well as to rationalisation of operational processes. Structural innovations are not just a renewal of the functionality of work structures but are also improvement of sales, marketing, organisation and logistics structures (Disselkamp 2012, p. 29).

Cultural innovation

Cultural, or sometimes called social innovations, are related to humans and their behaviour in a company. Cultural innovations intend to realise social aims, like the improvement of job satisfaction, accident prevention or job security. Various connections often exist between cultural and other types of innovations. In many cases, the transition from process to cultural innovations is fluent. Moreover, a product innovation can lead to a cultural innovation and the other way around (Vahs & Burmester 1999, pp. 77-78).

Marketing Innovation

Marketing Innovations affect both sales and purchasing markets. The objective is to increase either the turnover, to decrease purchase prices or to improve the quality of already existing output by finding new customers and suppliers. With expansion to national or international regions or the opening up of new customer segments (for example age or income classes) it is possible to tap into new sales markets. When it comes to the purchase market, it is important to continuously compare suppliers with other potential competitors. So a company can improve its own competitiveness in terms of better offers for their own clients. Besides the purchase market for goods, two more important markets exist: The financial market and the labour market. Both can provide new impulses for innovations. New financial sources open new business sections. Innovations at the labour market, like the recruitment of specialised staff from external regions, enables companies to cover their demand and ensure competiveness (Disselkamp 2012, pp. 26-27).

2.1.3 Characteristics of innovations

Innovations have some characteristics that distinguish them clearly from routine tasks. Thom (1980, p. 23) analysed the phenomena innovation and identifies four characteristics of innovation tasks: The high degree of novelty, the high risk or uncertainty, the complexity and the high conflict level.

Degree of novelty

The degree of novelty is of great importance regarding planning considerations of innovation tasks. Depending on the degree of novelty, an innovation can cause significant in-house and environmental changes connected with high amounts of investments in human and physical capital. With a higher degree of novelty, the difficulties and requirements of innovation management rise (Thom 1980, p. 26).

Horsch (2003 pp. 3-4) identifies two groups of innovation in this context: The basic or radical innovations and the evolutionary innovations. Basic or radical innovations are rapid changes, especially using new technology. This type of innovation enables a new product family or opens a new market field. A radical innovation is usually accompanied by significant changes in many departments, such as research and development, logistics, manufacture and sales. Furthermore, it is related to intensive and long research activities (Horsch 2003, p. 3). In comparison, evolutionary innovations are solutions, which are based on already existing technologies. It is a further development of successful and reliable products. It is typical for this project family that they are derived from previous experience and are only intended for stretching boarders. The investments are usually significantly lower (Specht & Beckmann 1996, p. 217).

Cooper (2010, pp. 16-17) considers three groups with a different degree of novelty. He states that between a radical innovation and innovations with a very low degree of novelty, there exists a third group: Innovations with a moderate degree of novelty. Those are new products and processes for the company, which are already present in the world market. This innovation projects have less success and should be avoided.

Risk and uncertainty

The risk can be defined by the amount of damage a company can suffer if an innovation project fails. Unfortunately, innovation projects are characterised by a high level of risk and uncertainty caused by its novelty. During development tasks, there is risk that a planned event is not completed or is completed too late, a production technology is not completed on time or a production technology is not controlled on time. The sales risk is high because estimations of prices and sales volumes are very difficult to do (Thom 1980, pp. 26-28).

Complexity

Innovation projects are not linear in time and interact with a high number of elements (Thom 1980, p. 29). Based on these thoughts, Vahs & Burmester (1999, p. 51) identify two dimensions of complexity: The time dimension and the quantitative-qualitative dimension.

The time dimension: Complexity arises due to an unpredictable variability of relevant facts (law, technology leap, market situation…) over time. Additionally, innovation projects can have loops and parallel tasks.

The quantitative-qualitative dimension: Innovations have an impact on almost all areas of a company and have relations to the environment (customers, suppliers, legislator). Therefore they have a high number of connections and elements.

Conflict level

The usually high uncertainty, degree of novelty and complexity of innovation projects lead, in most cases, to a very high conflict level. Figure 2.4 shows the connections between these innovation characteristics. New and unusual situations like innovative products, processes or structures lead to new and unknown conflict constellations. Likewise, the factor of uncertainty stimulates a high complexity and therefore the conflict level (Thom 1980, pp. 29-31).

The term ‘conflict level’ is mainly used in a negative sense. Nevertheless, conflicts are extremely important for innovative companies because ideas and creative solutions arise from dissatisfaction with a present situation and the desire for change and improvement (Vahs & Burmester 1999, p. 53).

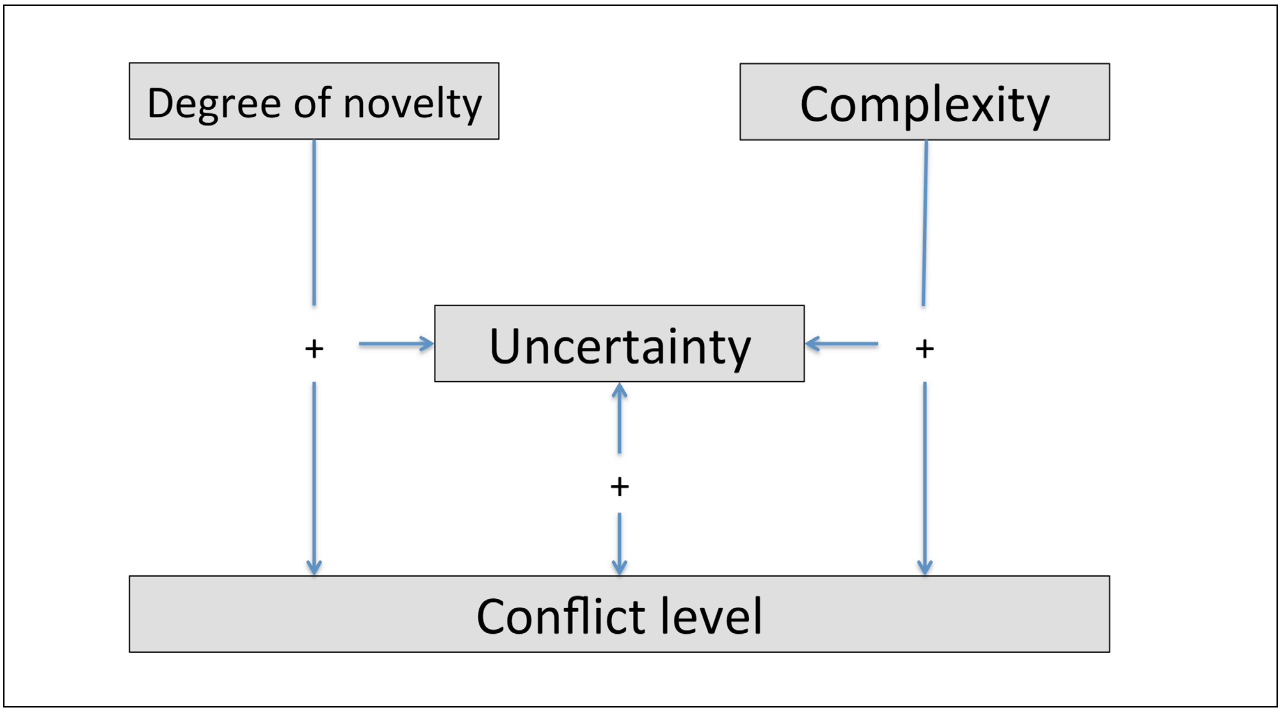

Figure 2.4: Characteristics of innovations and their dependencies (Thom 1980, p.391)

2.1.4 Aims of innovation

Innovations are always subordinated the economical, technical, social and ecological goals, which arise on the one hand from the company goals and on the other hand from the requirements of the business environment. The aims of innovations can be illustrated (Figure 2.5) with a “magic triangle” (Pleschak & Sabisch 1996 pp. 8-9).

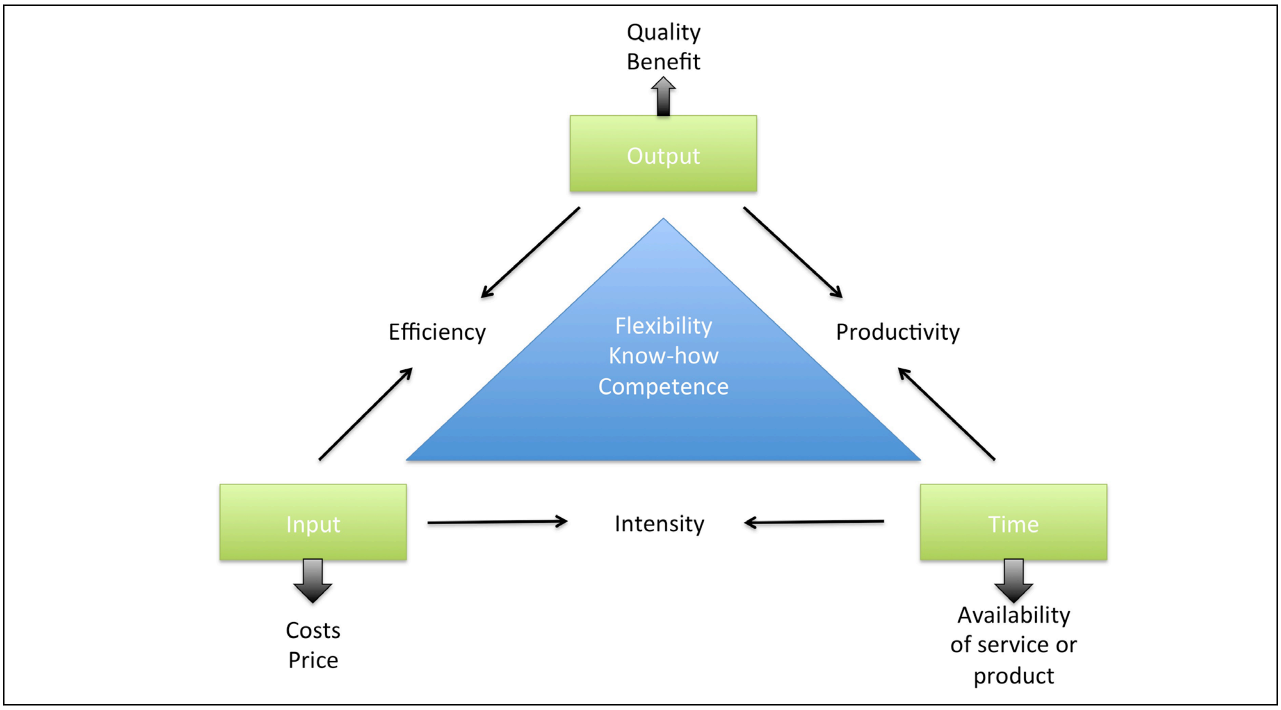

Figure 2.5: The magic triangle of innovation aims (Pleschak & Sabisch 1996, p. 9)

This triangle can be seen either from the view of the customer or from the view of the supplier. The customer wishes for benefits, which are the prime factor, an appropriate price as well as a good availability of the product. To fulfil these wishes, the supplier has to arrange the factors quality, cost and availability in an optimal configuration (Seghezzi 1994, p. 11).

The comparison of input and output provides information about the efficiency of an innovation process. This helps to reveal potential for optimisation measures. A good quality is of little help if either another competitor launches a product earlier or the product is not available due to a capacity bottleneck. Therefore, innovations have to contribute to improve the productivity as a proportion of output and time. Simultaneously, the relation between time and input must not be ignored. Here, flexibility means the ability to adapt to changes and to carry out the necessary tasks in a fast and focused way. Know-how and competence are prerequisites rather than the goals of innovations. Due to an ever-shortening half-life of knowledge it is important to strive for new information. Competences can be divided into three forms: the manual-technical, the technical-methodical and the social competence. To reach sufficient competence regarding a specific problem, all three forms have to be present (Vahs & Burmester 1999, pp. 58-61).

2.1.5 Driving forces and impediments of innovation

As well as the intention of reaching the aims of innovation, it is important to create an innovative environment. This chapter presents the driving forces for innovation as well as the impediments that could be counteracting.

Driving forces

A company can receive impulses for innovations from many different directions. All stakeholders, which are involved in success and failure of a company, are sources for innovation. Employees often have interesting ideas and costumers express their new wishes. With benchmarking results, advisors indicate new ways for the company and labour unions to initiate cultural or structural innovations (Disselkamp 2012, p. 43).

However, these stakeholders can be assigned to two groups. Each group again, can be assigned to one of the two main driving forces for innovation: these are the technology push and the market pull.

- *Technology push:*

Innovations driven by a technology push are primarily triggered by newly developed technologies. Areas of application for these technologies do not exist yet and have to be investigated (Vahs & Burmester 1999, p. 78).

Stakeholders that come into consideration are the department of research and development, suppliers, production and external scientific departments (Disselkamp 2012, p. 44).

- *Market Pull:*

Innovations induced by marketing pull have a high probability of success because they are initiated by the demand and needs of the customers (Vahs & Burmester 1999, p. 78). Horsch (2003, p. 40) highlights the importance of this driver of innovation. He states that the success of new products depends on whether or not they make a perceptible step forward in quality or cost and that innovations have to be developed with consideration of the needs, wishes and expectations of customers. Thus, market orientation is one of the basic strategic requirements for innovation management.

Stakeholder groups that can be the trigger for marketing pull innovations are not just customers, but also the departments for marketing, sales, and customer service as well as advisors and suppliers (Disselkamp 2012, p. 44).

In addition to the main driving forces, Cooper (2010, pp. 8-10) identifies the ever-shorter product life cycles and global competition as two additional promoters of innovations. The life cycles for products are significantly shorter than 50 years ago. Nowadays, products can be considered as old after some years, sometimes even after some months. Therefore, the pressure of finding new solutions increases with the decrease of life cycles. Additionally, internal markets are under pressure by all kinds of external markets because of globalisation. Any innovation can tap into any market worldwide, at any time.

Impediments, driving forces and success factors of innovations

Although the political decision-makers strive for an innovative climate, there are some impediments that slow down innovation drivers and influence companies negatively. These can be internal as well as external impediments (Vahs & Burmester 1999, pp. 37-38).

A potential for external impediments that should not be underestimated comes from the state administration. Lengthy authorisation procedures, complicated laws and bureaucratic regulations hinder the progress of innovation projects (Straßberger et al. 1996, p. 117).

Internal impediments arise from several sources. Mangers often reject innovation projects for the reason that they are costly. The intention is often to increase the profits for a short period. In doing so, they do not take into account the long-term sustainability for the company. This short-term profit increase is good for their own career but not for the firm. Furthermore, inadequate and rigid company structures slow down innovation projects, especially in big companies. A functional structure, for example, causes employees to become specialists more and more, without a holistic overview. Also, often too few people are involved in the innovation process. This can lead to a lack of information. The department of research and development, for instance, does not have enough information from the customers. Furthermore, people often hesitate to act due to the fear of making mistakes but who is not allowed to commit mistakes does not try anything new or different (Disselkamp 2012, pp. 53-59). Brooke & Mills (2003, pp. 191-193) add that even though innovation projects are risky, it does not mean that such projects surely lead to failure. It is important to face a calculable risk.

In addition, innovation projects show some characteristics that are of great importance to their success. Some of them can be derived from the aims of innovation. Quality has to be high in all stages of a project. Costs are no longer defined by the product but by the market. Therefore, target costing is important (Vahs & Burmester 1999, pp. 61-64). Time is a crucial factor. Fast progress creates advantage in competition, higher profits, and less risk of unintentional surprises. However, to omit phases in the innovation process to be faster than competitors usually ends in a catastrophe. (Cooper 2010, pp. 3 & 24)

Cooper (2010 pp. 91-124) adds, that beside this characteristic, one of the most important factors is a superior and differentiating product. This is because product superiority distinguishes, more than any other characteristic, a winner from a looser. Design and development are important but a special emphasis should be put on the preceding steps like screening, market studies or a feasibility study. He points out that companies often underestimate exactly these points, although the omission leads in many cases to project failures. Furthermore, an early and clear definition of the product and the related project has a positive impact on the outcome. Additionally, it is important to already think during development about a marketing strategy and service plan, since even the best product development will fail without a well thought-out implementation phase.

2.2 Innovation management

Innovation management is a discipline and has to be distinguished from the general term, ‘management’. In a further step, it is necessary to distinguish innovation management from technology management and from research and development activities. Additionally, the possible forms of internal organisation of innovation management have to be discussed. This is because the effectiveness of each structure depends strongly on the structural organisation of a company. In most cases, innovation processes are carried out as projects. The final part of this section therefore discusses different working forms that are suitable for innovation projects.

2.2.1 Delineation of concepts

As mentioned earlier, innovation projects can be distinguished clearly from conventional operational tasks. The innovation management must therefore also be differentiated from the traditional management.

The term management is often used with respect to some special business disciplines. The extension to financial, manufacturing or marketing management confirms this but also shows that the meaning of ‘management’ seems almost arbitrarily extendable. Originally, this term derives from the Latin word "manus" = hand. Management in a figurative sense means, to take charge of, to form, or to shape. From an operational perspective, management deals with leadership, control, development, and design of business organisations (Oelsnitz 2009, pp. 7-8).

An organisation is usually constructed in a way, which enables the management of frequently recurring routine processes fast, safely, reliably and in a cost-effective way. An organisation is comparable with a long-term investment. It only pays off if it is permanently ensured that all recurrent tasks are carried out systematically and efficiently. Innovations, on the other hand, are unique and initial events that are difficult to manage. Innovations are not predictable. The management cannot rely on fixed processes and procedures. In many cases, innovation projects are considered as troublemakers within the company. Therefore, innovation management has to be separated from routine management. Nevertheless, at a certain point it has to be incorporated again (Hauschild 1993, p. 27).

Innovation management is by far not just an internal issue. A key task is to communicate with external partners during the innovation process. This has to be solved within three subtasks (Hauschild 1993, p. 149): the partners have to be integrated into the system, the integration moment has to be defined and the success that results from the cooperation has to be fairly divided.

Innovation Management embraces all activities up until the market launch of a new product, including all support functions in the areas of personal management, organisation, finance and accounting. Thus, it is more extensive than research and development management, which represents a part of innovation management that is related to the natural-scientific and technical area (Vahs & Burmester 1999, p. 47).

Furthermore, research and development management has to be distinguished from technology management. Technology management should ensure the technological competitiveness of a company, based on the observation of competitors and technology forecasts. It aims to enlarge the technological potential. In some cases, this is even realised by means of alliances with other companies (Vahs & Burmester 1999, pp. 46-

47). Figure 2.6 illustrates the range of innovation, research and development and technology management within the steps of an entire innovation process.

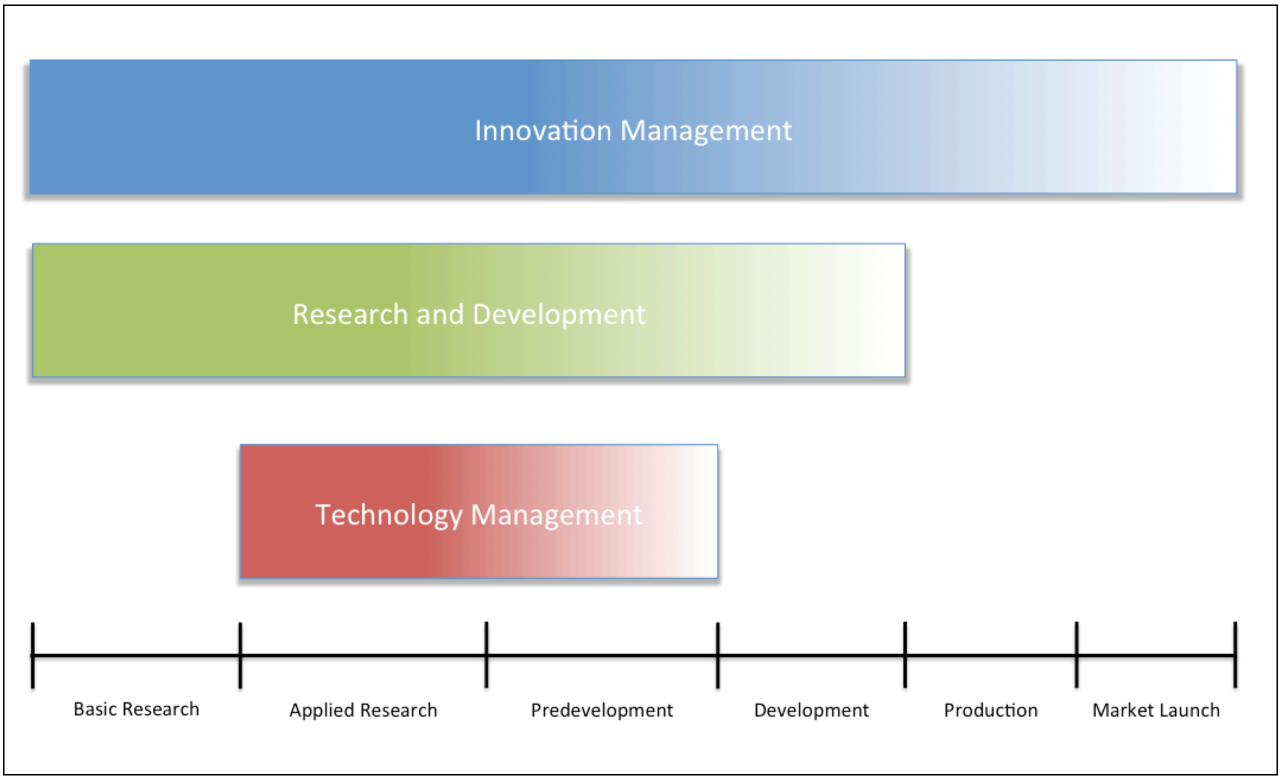

Figure 2.6: Range of innovation, technology, and research and development management (Macharinza 1995, p. 600)

2.2.2 Incorporation of innovation management into the holistic management

Innovation management may either be incorporated into the organisation in the form of centralised or decentralised management. In addition to the degree of centralisation the extent of the powers assigned to the innovation institutions has to be decided. The innovation function can either be integrated into the corporate organisational unit with limited authority or as equal line function (Vahs & Burmester 1999, p. 302).

Centralised

In order to institutionalise the innovation management centrally, an especially dedicated organisational unit has the task of implementing all running innovation projects within a company. Basically, either a line function or a staff position can be considered (Vahs & Burmester 1999, p. 302).

Staff positions perform specialised tasks and generally have no decision-making powers. Staff positions are always tied to an operative commander. They are intended to relieve them quantitatively and qualitatively in terms of preparation, implementation and monitoring of decisions (Bühner 2004, pp. 133-135). Due to this situation, staff is only meaningful in functionally structured companies. In this case, the planning and coordination of all innovation activities can be taken over by a staff position but this is usually only appropriate for small to medium businesses of a manageable size (Vahs & Burmester, pp. 303-304).

Unlike the case of the staff organisation, an innovation management, which is located on the same level of power as all the other units at this organisational level, also has the same rights and obligations. Thus, the enforcement of specific innovation goals is much easier. This approach represents the classical form of innovation management regarding functional organisations (Vahs & Burmester 1999, pp. 304-305).

Decentralised

Applying a decentralised innovation management, the tasks are distributed across several units. In this case, basically two implementation alternatives remain. Firstly, the innovation management is considered as part of all functional areas or divisions, or secondly, the innovation tasks are carried out by decentralised staff positions (Vahs & Burmester 1999, p. 307).

An innovation management unit in every division or functional area increases flexibility. It is possible to respond faster to small changes. These benefits, however, are associated with increased coordination effort. This alternative structure of a functional organisation is largely theoretical due to the need of significantly more resources and the comparatively small additional benefits. In contrast, it is meaningful for divisional structures with a high diversification of the product range (Vahs & Burmester 1999, pp. 308-309).

Innovation Management in the form of decentralised staff positions has more or less the same advantages and disadvantages. To ensure complete coordination within the company, a central staff position can be added for carrying out the necessary coordination tasks (Vahs & Burmester 1999, pp. 308-309).

2.2.3 Structuring of innovation management

In addition to the organisational integration of innovation management into the business organisation, the question arises, how it can be structured internally. Basically is a subdivision in types of execution, objects or regions conceivable. The specific models are illustrated in Figure 2.7[2] (Vahs & Burmester 1999, p. 312).

[2] IM is an abbreviation for Innovation management

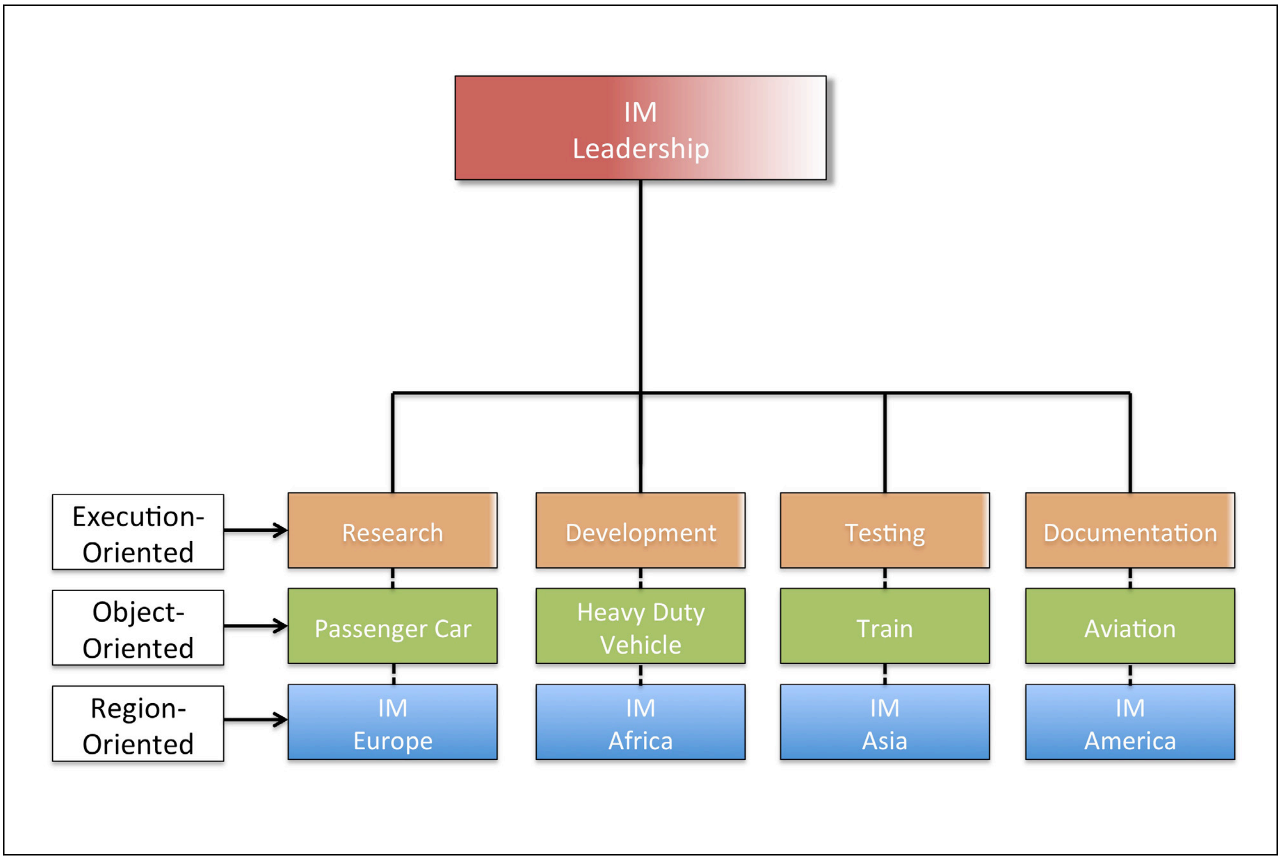

Figure 2.7: Structure forms of innovation management (Vahs & Burmester 1999, pp. 313-314)

Execution-oriented subdivision

A subdivision into types of execution groups those task in different organizational units, that have similar content. However, this structure should only be recommended if a company is characterised by a homogeneous and stable product portfolio. Additionally, there is a risk of communication problems between the units, which may hinder the information flow (Vahs & Burmester 1999, pp. 312-313).

Object-oriented subdivision

The object-oriented classification is based on the performance program of the company. The subordinated organisational units act relatively autonomously. Such an organisation of innovation management makes a lot of sense when the performance program is heterogeneous, as is the case for divisionally organised companies. As well as the orientation towards product groups, the division criteria could also be determined by technical disciplines or projects (Vahs & Burmester 1999, p. 313).

Region-oriented subdivision

In this case, the innovation management is subdivided by means of regions. An innovation management is introduced to each region, whereas the department of research and development remains central and assumes the coordination of the innovation process (Vahs & Burmester 1999, pp. 313-314).

2.2.4 Working-forms for the realisation of innovation projects

Litke & Kunow (2006, p. 15) define a project as a complex and innovative task that cannot be solved with the permanent and conventional structures of a company. Projects are unique and have a defined start and end. Furthermore, they show an interdisciplinary cross-functional character (Seibert 1998, p. 276).

Due to these facts, these innovation projects are difficult to integrate into a system or permanent structure of a company. On the other hand, projects in particular need frequent coordination among the organisations. Project management can help to solve these problems (Vahs & Burmester 1999, pp. 314-315).

Horsch (2003, p. 197) and Seibert (1998, p. 286) define four different basic models of project management that are, depending on the project, more or less useful:

- Line project organisation
- Staff project organisation
- Matrix project organisation
- Pure project organisation

Line project organisation

Line project management does not cause or imply any change within the company's organisational structure. An employee of the most involved line is used as project manager. It is not necessary to create new jobs for the project nor does the project leader receive additional discretionary powers. Thus, the main advantage of the project management in the line is that it's easy setup. It is problematic, however, when the leadership moves from project phase to project phase, between the involved departments. This often leads to duplication of work at the time of the hand-over of intermediate results (Seibert 1998, p. 286).

This form of project organisation is useful for smaller projects, for small modifications with a strong connection to one department. It is rather inappropriate for innovative and interdisciplinary projects. It involves a certain risk of one organisation or department dominating. Additionally, in most cases, the handover causes a loss of time (Horsch 2003, p. 198).

Staff project organisation

In the case of a staff project organisation, the functional hierarchy of the primary structure remains unchanged and is merely complemented by a staff position that represents the project coordinator. This position must be located highly enough within the company hierarchy so that he has direct access to executives. The project coordinator has no discretionary power but just assists and consults. The high flexibility of this structure is an advantage because several projects can be conducted at the same time, almost without any additional organisational effort. The disadvantage is that often nobody feels responsible for the projects. Even though this form of project organisation is the most inefficient, it is applied frequently in real life situations due to the reason that it is easy to implement (Litke 2007, p. 71).

Matrix project organisation

Within the matrix project organisation both the project leader and the line manager have authority. The project manager's task is to bring about decisions of involved employees. Additionally, he is responsible for project schedules and costs. Employees are responsible for the factual content. This form of organisation is recommended when a company deals with a large number of projects, where many departments and organisations are involved. The advantages are that the project leader feels fully responsible for the project and that flexible staffing is possible (Keßler & Winkelhofer 2004, pp. 27-28).

Due to the fact that several projects are usually conducted at the same time, conflicts are possible. Therefore, clear priorities for the projects are necessary to prevent certain departments from being overloaded (Horsch 2003, p. 200).

Pure project organisation

Pure project organisation forms an independent organisational unit, like a task force or a project department. For the duration of a project, the employees work only for this project department and their only boss is the project manager. After completion of the project, the organisation is either dissolved or converted to a future project. Advantage of the pure project organisation is the unlimited authority of the project manager who can then avoid conflicts more easily. The pure project management also leads to a high level of identification of employees with the project and to fast communication channels. The problem, however, is the high conversion effort. An employee must be completely removed from the primary structure and at the end of the projects, there are often no adequate following positions for these workers. The risk of costs increases, as machinery and equipment need to be purchased for the project team. The pure project organisation is therefore only useful for long and big projects, in which the disadvantages mentioned above are far outweighed by the benefits of the organisation (Seibert 1998, pp. 291-292).

2.3 Innovation strategy

Each company has a kind of innovation strategy. For many employees, nevertheless, innovation still seems chaotic and unpredictable. It is true that a high level of uncertainty accompanies innovation, however, the framework for action has to be described. Assumptions concerning the technological feasibility, the competitive behaviour and customer behaviour are necessary. If an assumption does not apply, the company can still learn for the future (Gassmann & Sutter 2008, p. 25).

Vahs & Burmester (1999, p. 97) add that innovation does not emerge from nothing. It is based on the focused action of executives. Furthermore, the innovation strategy is the initial point of a competitive innovation processe. To turn an invention into a successful innovation, optimal resource allocation is essential. The innovation activities have to be aligned with the holistic strategy.

2.3.1 Concept of strategy

The term ‘strategy’ has its origin in the Latin words “stratos” = army und “agein” = lead. Strategy stands for the art of army leadership but 50 years ago the term was transferred from the military scene to the management science. In this regard, strategy means the planning of a sequence of steps that are aligned with fulfilment of a certain goal (Vahs & Burmester 1999, pp. 97-98).

The strategy of a company is composed of several components. The innovation strategy is one of these. It is operational and action-oriented and aims to use the limited budget wisely. The innovation strategy includes the following points: the goals of the complete product development, the strategic areas for innovation, the right allocation of resources and the strategy for each area to generate competitive advantage in comparison to the competitors (Cooper 2010, p. 397).

In order to complete these points in the best possible way, it is important to use the correct information channels and apply the right type of strategy to each situation.

2.3.2 Types of innovation strategies

Due to a large number of approaches to classify business strategies in scientific literature, it is difficult to distinguish types of strategies in a general way. The following discussion therefore refers to four differentiation criteria:

- Strategy differentiation regarding the incorporation into the company strategy
- Strategy differentiation regarding behaviour and acting
- Strategy differentiation regarding market entry or timing
- Strategy differentiation regarding the competition

Strategy differentiation by the incorporation into the company strategy

An important task of the innovation strategy is the linking between all product development efforts and the holistic company strategy (Cooper 2010, p. 396). Two possible ways of incorporation of the innovation strategy into the company strategy are conceivable:

- *Meta strategy:*

A meta-strategy incorporates all functions of the company into the innovation strategy process. In this manner, synergies can be discovered and used. The entire knowledge of all functions is the base of the innovation process. A disadvantage is the relatively high communication and coordination effort due to the need of balancing the functions. Therefore an essential task of the strategy is to integrate all knowledge to the innovation process and promote the ability of innovation of the company (Vahs & Burmester 1999, pp. 107-108).

- *Functional strategy:*

In this case, the innovation strategy is completely embedded in the research and development department. This strategy determines future technological fields and the research and development intensity and contains guidelines for make-or-buy decisions. Synergistic effects can often not be achieved (Vahs & Burmester 1999, p. 107).

Strategy differentiation based on behaviour and acting

Hauschild (1993, p. 81) distinguishes between two types of innovation strategies:

- *The defensive type:*

The defensive type pursues a strategy of innovation outsourcing. It is noteworthy that this type often has an offensive marketing strategy simultaneously. In these companies, innovation is apparently under such high pressure of demand that technological originality is neglected and technological cooperation is mandatory.

- *The offensive type:*

The offensive type aims to create its own innovations. Offensive companies put much more focus on specialised research in order to create a high number of patents. In such firms the so-called, “not invented here syndrome”, can be observed frequently. This means that offensive acting companies favour in-house development over innovation from sourcing.

Strategy differentiation based on market entry or timing

The market entry strategy or timing strategy determines when a company should be present in a market and when it should withdraw a product. Literature distinguishes the pioneer, the early imitator and the late imitator.

- *Pioneer strategy:*

Generally, the statement "do not waste time" contains the pioneer’s first advantage. The strategic focus at the time of market entry lies on the customer-oriented market development. The market set up must therefore be accomplished parallel to product development. As customers gain experience, the feedback for product optimisation can be used for building customer and brand loyalty. Another advantage but also a challenge, is to build market barriers. On the other hand, the marketing costs are a particular risk only the pioneer has to bear (Schäppi et al. 2005, p. 208). Fischer (2001, pp. 140-141) adds other advantages like the possibility of safeguarding recourses and a lead regarding commercial issues. By ‘recourses’, relationships to suppliers and customers, strategic plant positions, human capital and mineral resources are meant. The commercial lead results in a very high recognition factor, which makes it difficult for followers to assert themselves when entering a specific market.

- *Early follower strategy:*

A follower tries to systematically search for possibilities of modifying the innovations of others and to avoid the first step on a market. The early follower observes the market success of an innovator and tries to optimise the product. Usually, this is true for companies with a weak research department but a high investment capital. Since success depends heavily on the capital potential, it often makes it difficult for small and medium sized companies to survive (Pepels 2006, p. 9). The main advantage of an early follower is that he can use, or at least a proportion, the pioneer’s already finished work. For an early follower, it is recommended to plan the market entry in a very targeted and focused way. He can, for instance, raise the level of benefits through a higher product potential, a lower price, or a combination of both. This is crucial due to the necessity of breaking through the barriers created by the pioneer (Schäppi et al. 2005, p. 209).

- *Late follower strategy:*

The late follower tries to launch products on an already stable market. This market of interest, continues to grow and the mature phase is not yet reached. This means that the late follower can find possibilities for placing his products (Töpfer 2007, p. 538). The entry strategy of these ‘me-too’ innovations is often marked by aggressive price reductions and strong commercial efforts. This leads on the one hand to a price advantage and enables on the other hand a breakthrough of the existing entry barriers. A second approach is the niche strategy. Due to the increase of experience of the customers, new market segments that can be used often arise. So the late follower avoids the confrontation with competitors and circumvents the barriers (Schäppi et al. 2005, p. 209).

Strategy differentiation based on competition

In order to create above-average success within an industry field, a company has to generate competitive advantage. The two basic possibilities are to pursue a low cost strategy or a differentiation strategy. Porter (1998, pp. 11-16) identifies three types of generic strategies (Figure 2.8) based on these two types of competitive advantage in combination with the scope of activities:

- *Cost leadership:*

Cost leadership aims to achieve a cost advantage over its competitors, which is mainly realised with standardised products and processes and the production of large quantities. The quality of product characteristics with relevance to the customer is not worse than that of other competitors. When striving for cost leadership, it is important to be “the cost leader” and not just one of many. If forcing the competitors to focus on other strategies does not work out, there can be disastrous consequences.

- *Differentiation strategy:*

The differentiation strategy aims to make products stand out by providing unique features for customers with performance and user benefits. Thus, higher prices and quantities can be achieved. Intensive research, development and innovation activities are required in order to realise the unique features.

- *Focus strategy:*

Unlike cost leadership and differentiation strategy, the focus strategy concentrates on a narrow industry segment, either with a focus on costs or differentiation. The success factor comes either from a higher customer orientation and adaptation to specific customer needs or from a specific technical expertise.

- *Stuck in the middle:*

The attempt to be cost leader and differentiator at the same time is seductive but this should be definitely avoided in the long term, since costs and differentiation are in contradiction.

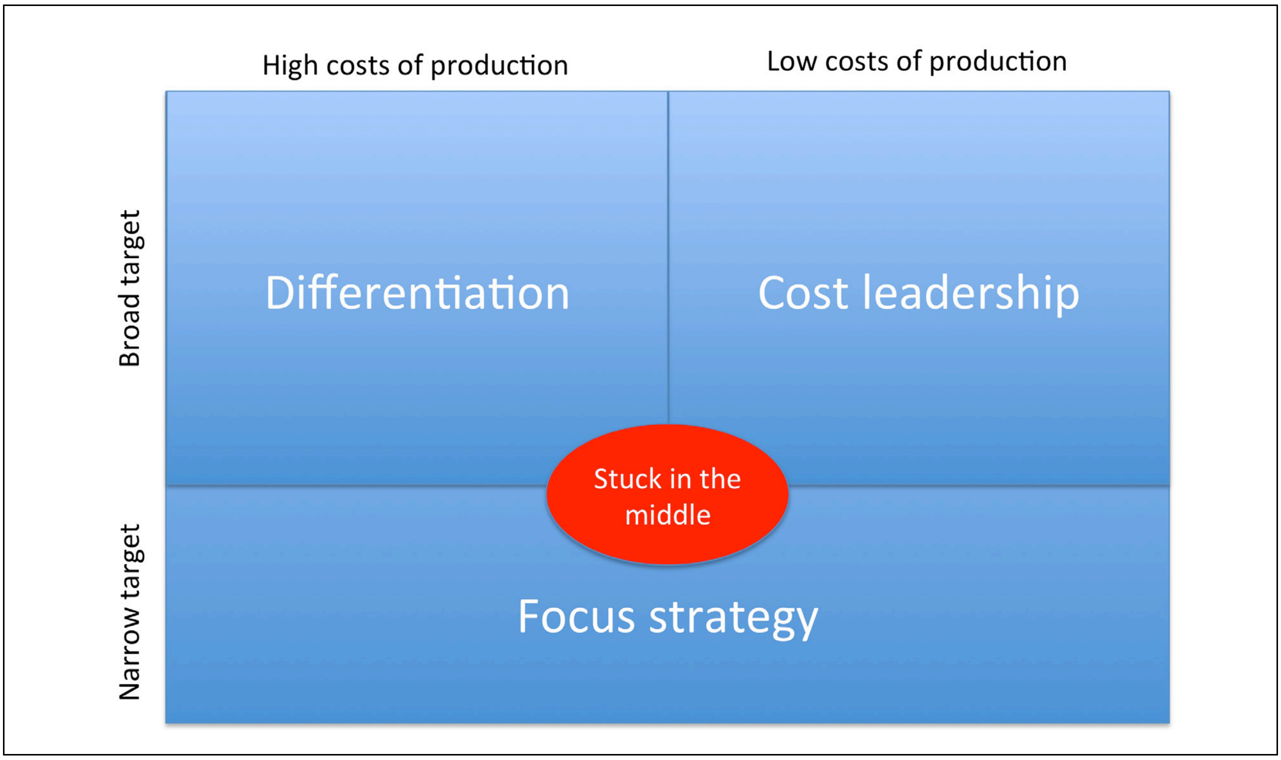

Figure 2.8: The three generic strategies (Porter 1988, p. 11)

2.3.3 Types of innovation channels

As mentioned above, the innovation strategy has as an aim the optimal allocation of resources. To do so, it is important to understand where potential for innovation comes from. Three strategic alternatives can be distinguished (Seibert 1998, p. 145):

- External sources
- Internal sources
- Cooperation, alliances, and joint research

External sources

The acquisition of external know-how is particularly considered if innovations are to be implemented very quickly and without the need of internal research and development capacities. Some of the main forms of external know-how acquisition are (Seibert 1998, p. 148):

- *Contract research*:

In this case, a company hires another company, research institute or other external specialists to investigate or develop on its behalf and at its own risk, a product or process. This approach is especially suitable for one-time developments with low synergies to the recent research and development activities of a company.

- *Licensing:*

When licensing, the company acquires an objectively, place or time limited right to use existing technical knowledge. The purchase of a license is useful, especially when a fast market entry is sought and the company only has limited internal skills.

- *Acquisition:*

Another option is to buy other companies, which already have the required technological know-how. Thus, a major expansion of its own technical and market-related competence area is possible. The acquisition is often the only way to get into new markets or to acquire knowledge of strategic technologies for the future that have not been investigated yet. Moreover, a company purchase could also be taken into account when a quick market entry is sought and a license adoption is not possible.

Internal sources

Internal research and development includes the use of internal financial, material and human resources for the research and development of new technological solutions to problems. Advantages are the ability to protect the new technology, prestige and image enhancement and the direct control of the innovation process, regardless of a third party. Disadvantages of internal research and development work are the higher resource commitment, the higher expenses and the higher expenditure of time. Due to the high resource commitment, it is not possible to control all technologies that are needed. A company should therefore focus on a few key technologies. In addition to targeted research and development activities, the employee suggestion system represents a source for innovation (Seibert 1998, pp. 145-146).

Cooperation, alliances and joint research

Research and development cooperation are agreements between two or more parties, which strive for a joint purchase or exchange of technical knowledge. There are both horizontal alliances between partners of the same industries and vertical cooperation with suppliers and consumers. A prerequisite of a long-term cooperation is the similar interests of the involved partners (Seibert 1998, pp. 146-147).

2.4 Innovation process

Innovations are, unlike inventions, not a point in time but rather process-based. The time span of an innovation process can be divided into different phases and includes activities that are necessary to move from an idea to its practical implementation (Tsifidaris 1994, p. 12).

Etymologically, the word, ‘process’ comes from the Latin word “procedere” = progress or proceed. A process is a set of time-based and functionally related activities that serve a common purpose. Each operation of the process may itself be a process that is again composed of elementary operations. Thus, a sub-division into main and secondary processes is possible (Hansmann 2006, p. 200).

Processes have the following characteristics (Hauschild 1993, pp. 278-279): A process consists of a sequence of activities. However, it can be the case that some of the activities run parallel. Processes have a defined start and end time. By focusing on different outcomes, processes can be isolated from each other. This isolation is a necessary prerequisite for the identification of innovation processes.

Compared to other processes, innovation processes show the following properties (Cooper 2010; Hauschild 1993, pp. 278-279):

- *Uncertainty of activities:*

As the innovation process is performed for the first time, there is no specific experience of the type, scope, duration and linking of activities. The output object is, in many cases, not yet precisely defined. The required capacities are difficult to estimate.

- *Time pressure:*

The time pressure is a constant companion of the innovation project. Proceeding fast creates competitive advantage, brings higher profits and lowers the risk of surprise.

- *Interdisciplinary processes:*

An innovation project usually involves a large number of people, with different work contributions. High specialisation is frequent and increases the risk of gaps between the steps of the process.

In literature, a high variety of approaches to subdivision of the innovation process can be identified in phases, steps or stages. The intention of this breakdown is to make the whole system manageable and the typical methods and purpose of each phase should be made visible. However, the individual concepts differ more or less from one another. On the one hand, they often have significantly different abstraction levels and on the other hand, the focus is put on different aspects of the innovation project. The more simply a model presents the process of innovation; the easier it is to transfer to real world. The abstract description has, however, only a relatively small meaning for concrete innovation processes. Detailed procedures are illustrated, by contrast, very meaningful for a small field of application but they often build on specific criteria, such as company size or industry type (Vahs & Burmester 1999, pp. 82-83).

This chapter presents some recognised models to provide an overview of the existing models in literature.

2.4.1 The Cooper model

The stage-gate model was developed by Robert G. Cooper to optimise innovation and development processes. The stage-gate approach divides the innovation process into a set of discrete sections, with each consisting of a subset of mandatory, cross-functional and parallel activities. Each section is entered through a gate. These doors control the process and serve as checkpoints for quality control and termination or continuation of the project. The sections between these gates are called stages (Cooper 2010, p. 145).

The stages

Usually a stage-gate process consists of five or six stages. Each section serves to collect information, which is necessary to proceed to the next gate. As mentioned before, each stage is structured across divisions. There is no distinct research and development or marketing section. Each stage consists of a certain amount of parallel activities that are performed by employees from different functional areas of the company while the use of resources is growing from stage to stage (Cooper 2010, pp. 146-147).

The gates

The gates fulfil the same function as the coordination between coach and team in any sport. The whole team comes together and all the information is gathered. A decision on the future of the project is made on the basis of this information. All stages of the process show similar structures (Cooper 2010, pp. 147-148):

- *Results:*

The project manager and his team need to present certain results. These target values are set at the previous stage so that the expectations of the management are clearly known by the team.

- *Criteria:*

The project is evaluated using certain criteria. All the necessary criteria have to be met in any case. Desirable criteria are awarded with points. These points help to set priorities between projects.

- *Defined outputs:*

The output includes an approved action plan for the next stage, a list with all results that have to be shown at the next gate and decisions on the future of the project (termination or continuation).

Figure 2.9 shows the basic structure of a stage-gate process with five sections.

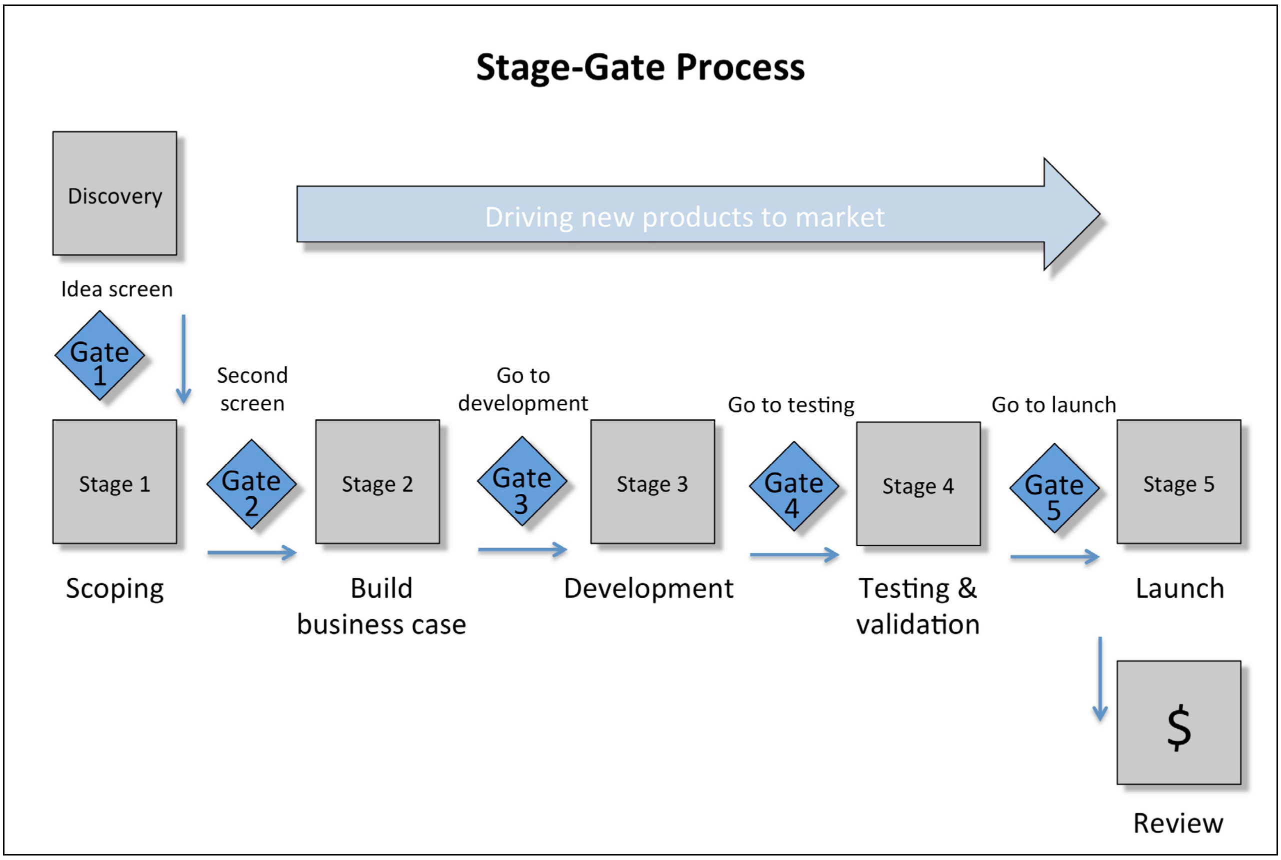

Figure 2.9: Stage-Gate Process (Cooper 2010, p. 146)

As mentioned several times, the pressure of time is a key element in the innovation processes. Therefore, Cooper has tried to improve his Stage-Gate Process to make it even faster and to use resources more efficiently. This so-called Third-Generation Stage-Gate Process is a natural evolution of its predecessor and has six fundamental phenomena (Cooper 2010, pp. 166-171):

- *Flexibility:*

The amount of risk, uncertainty, and information determine which sections are needed and which can be left out. An abbreviation however is only recommended for small projects with low risk.

- *Fuzzy Gates:*

If a mandatory criterion is unclear, the project must not be placed entirely on ice but can be pushed forward in a restricted way. It comes to a decision whether to proceed normally or if termination is necessary once the open point is clarified.

- *Fluidity:*

Overlaps and the beginning of tasks from following stages in advance are allowed but the gates remain.

- *Focus:*

The process is like a funnel. Only the most promising projects will be kept in the portfolio. The rest are eliminated and the previously provided resources are divided between the remaining projects.

- *Mediation and facilitation:*

A referee ensures a good process flow and controls compliance. He manages the team and helps to overcome difficulties.

- *Forever Green:*

The process can always be developed further, improved and modified in order to adapt it to changes within the company.

Although this process has some advantages, caution is advised. An implementation is only useful if the simple form of the Stage-Gate Process is already installed. It is like driving a car. The beginner holds to strict rules and will therefore be slightly less efficient. The experienced drivers, however, can assess the risk when he violates certain rules and thus arrive faster. The Stage-Gate Process of the third generation should therefore only be used when there is already a certain level of process experience, as with the implementation the risk of fallibility increases. Figure 2.10 shows a Third-Generation Stage-Gate Process (Cooper 2010, pp. 171-172).

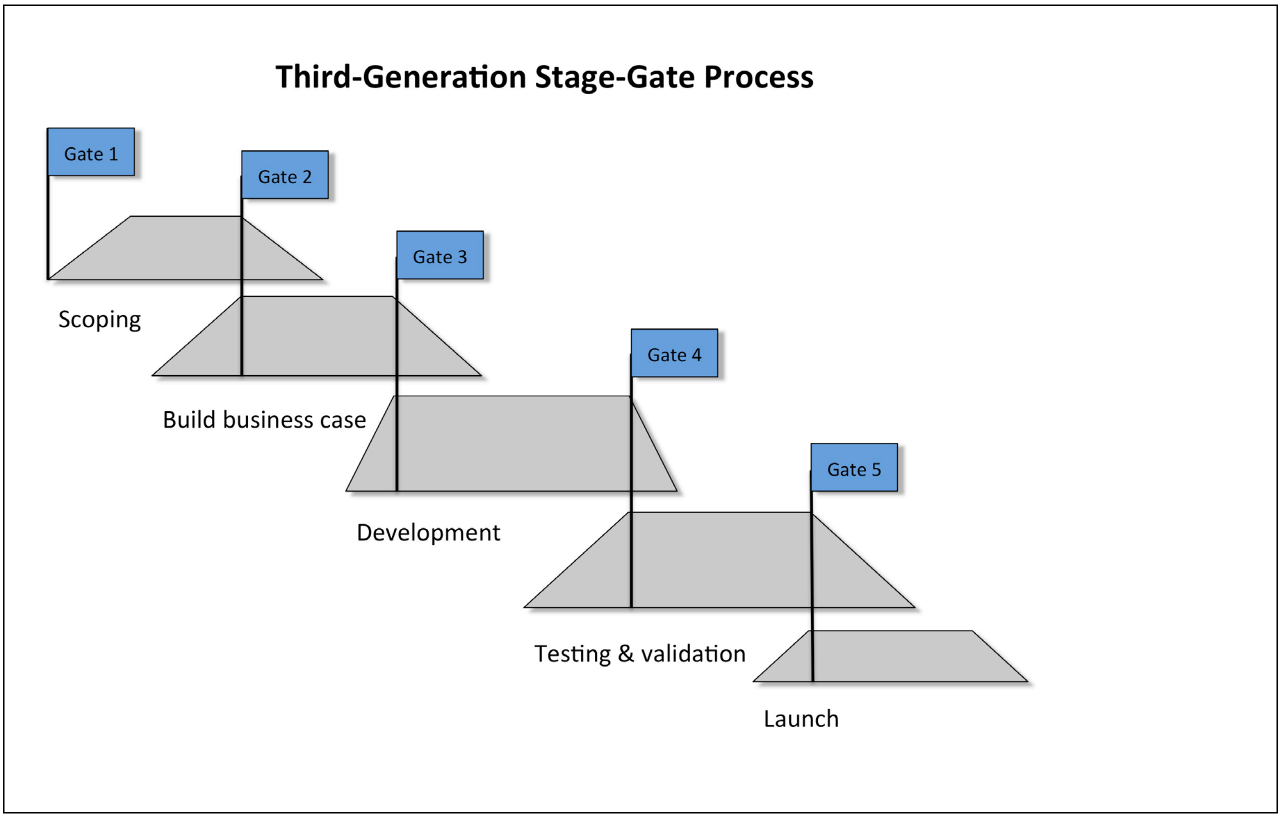

Figure 2.10: Third-Generation Stage-Gate Process (Cooper 2010, p. 169)

2.4.2 The Brockhoff model

The Brockhoff model is not an exact process scheme. The innovation process is roughly structured and simple (Figure 2.11). Both, the processes activities (research and development, launch a new product on the market…) and their results (project idea, invention…) are included and represent the innovation in a narrow sense (Vahs & Burmester 1999, pp. 84-85).

Brockhoff notes that, with the innovation, the process is still not complete and therefore adds the step of diffusion to his model. Only with the establishment of a product on the market success can be achieved. If this phase is neglected, economic failure can occur very quickly (Brockhoff 1992, pp. 27-29).

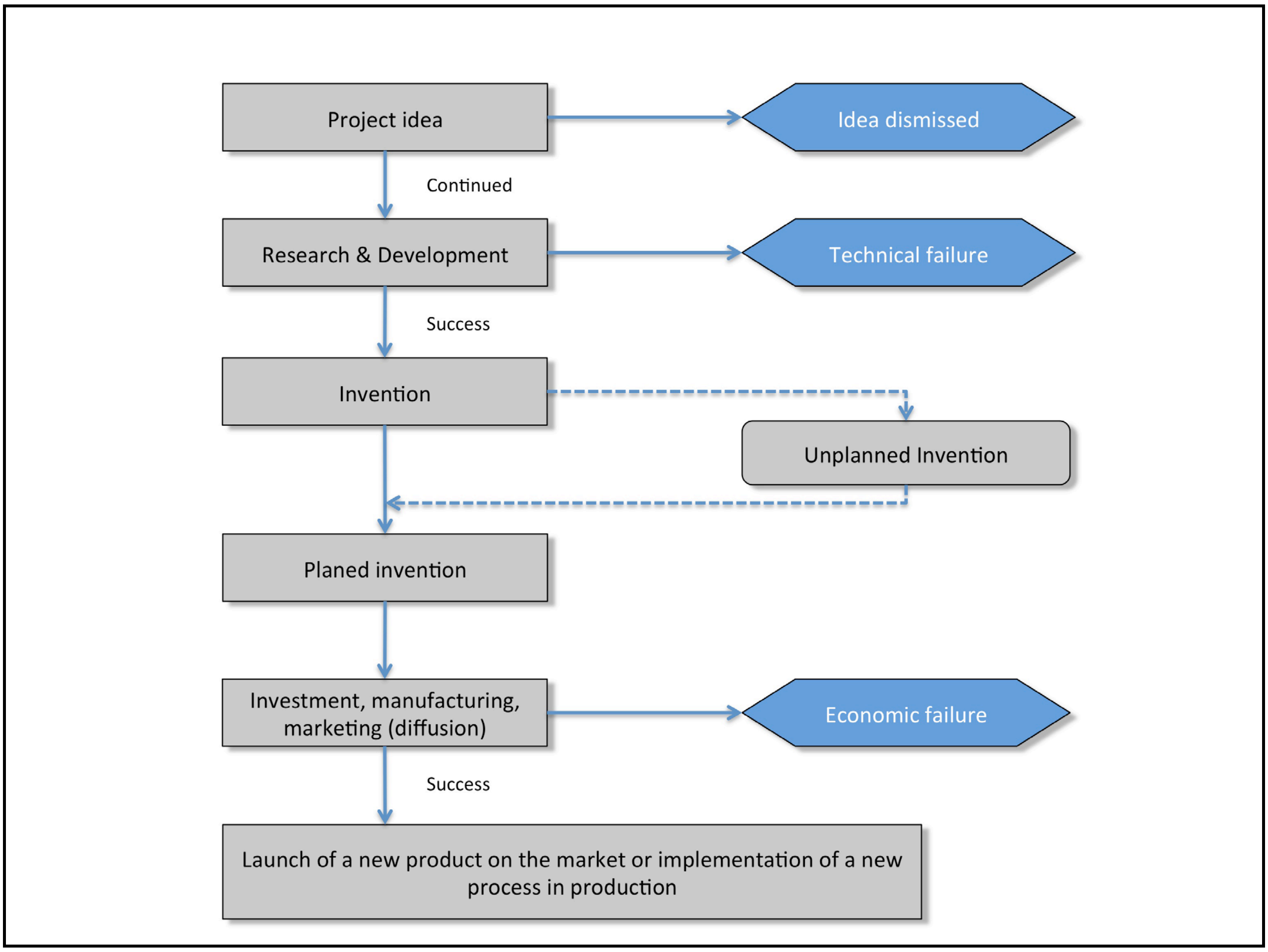

Figure 2.11: Phase model of Brockhoff (Brockhoff 1992, p. 29)

2.4.3 The Thom model

In 1980, Thom had already developed a pioneering three-phase scheme. The main phases of this model can also be found in many other models (Vahs & Burmester 1999, p. 84).

Thom noted that at least the phases of idea generation and acceptance are essential in a process of innovation. Nevertheless, this division is in his opinion too coarse, since the decision phase is considered too little. Thom therefore extended the rudimentary two-phase model to a third phase (Thom 1980, pp. 51-53):

- *Idea generation* (production of ideas)
- *Idea acceptance* (reduction of conflict, uncertainty, and risk)
- *Idea realisation* (implementation of an idea)

These main phases can still be further subdivided so that the following overall model results (Figure 2.12).

Phases of the innovation process		
Main phases		
1. Idea generation	2. Idea acceptance	3. Idea realisation
Specification of the main phases		
1.1 Determination of the search field	2.1 Examination of the idea	3.1 Concrete realisation of the idea
1.2 Idea-finding	2.2 Preparation of realisation plans	3.2 Sale of the idea to an addressee
1.3 Idea-suggestion	2.3 Decision for a realisation plan	3.3 Control of acceptance

Figure 2.12: Phase model of Thom (Thom 1988, p. 53)

2.5 Main phases derived from Thom

As mentioned earlier, the three main phases of the model of Thom pointed the way forward for the development of numerous other models. In fact, almost all models similarly involve the three main phases. The model of Thom is clearly structured and used as a frame structure for the practical part of the work. This chapter discusses both the main phases and its specifications as well as all sub-points.

2.5.1 Idea generation

The number of ideas produced to solve problems can be seen as an efficiency criterion for the phase of idea generation, since a large number of ideas increase the probability of usable ideas. Moreover, the proportion of usable ideas to the overall production of ideas can be considered as another criterion of efficiency (Thom 1980, pp. 77-78).

This suggests that a process for the targeted generation of ideas is necessary. With search fields, the production of irrelevant ideas can be significantly minimised. The second step of this phase (idea-finding) is to try to generate a high number of ideas with the help of special methods and techniques. Subsequently, the phase of idea-suggestion selects the most promising ideas in order to focus the usually limited resources on the most promising ideas (Thom 1980).

Identification of search fields

The identification of search fields sets the topics for the idea generation in order to purposefully realise the vision of the company. Search fields have a focusing effect on the problem-relevant areas. This leads to a simplification in both the extraction and the exploitation of ideas (Gaubinger et al. 2008, pp. 62-63).

Seibert (1998, p. 159) stresses the importance of the search fields for an effective and efficient innovation planning. The search fields should be on the one hand so precise that they allow a targeted orientation of idea generation, but on the other hand defined broadly enough to stimulate the search for novel and creative approaches. A suitable instrument for determination of promising areas for the idea search is the search field matrix.

- ***Search field matrix***

The search field matrix compares the know-how strengths and core competences of a company with a list of attractive market segments (Seibert 1998, p. 159):

Know-how strength: All divisions are analysed to determine special abilities compared to other companies.

Attractive market segments: Attractive market segments for innovation are characterised by high growth rates or by any other recognizable development potential (e.g. change in legal provisions). Studies of future markets and technologies as well as interviews with marketing professionals contribute to identify such segments.

The search field matrix is evaluated by checking for each market segment whether the previously determined know-how strengths are applicable and promising. Subsequently, the search field proposals derived from the search field matrix are evaluated. The most attractive ones are selected (Seibert 1998, p. 159).

Idea-finding

In this phase, concrete approaches for innovations should be developed. Since the failure rate of ideas is very high during the innovation process, as many customer-oriented and original ideas as possible are needed to improve the probability of market success (Seibert 1998, p. 161).

Various idea finding methods exist. In literature, the methods are distinguished according to the degree of novelty and the origin of the idea (Pepels 2004, p. 390; Seibert 1988, p. 161; Vahs & Burmester 1999, p. 137).

Idea finding methods according to the degree of novelty

Vahs & Burmester (1999, pp. 137-138) as well as Seibert (1998, p. 161) note that ideas do not need to always be entirely new. In many cases, problem solutions already exist and just need to be systematically searched for and found. As a result, scarce resources are conserved, and management does not run the risk of reinventing things. The disadvantage of idea collection is that the created ideas are usually also available to other competitors and only have a low degree of novelty. To counteract this disadvantage, the production of ideas can be used as a complement. The systematic generation of novel ideas is more resource consuming but also leads to more original ideas.

Idea finding methods according to the origin

Ideas are either generated company internal or external. Typical internal sources are the product application of employees or the analysis of complaint reports. As examples for external sources, the patent research and reports of research institutes can be named (Seibert 1998, p. 161).

In most cases, the use of special creativity techniques like brainstorming, brain writing, mind mapping, synectics or morphological boxes is needed in order to create a sufficient number of ideas (Pepels 2004, pp. 391-399).

Figure 2.13 shows an overview of important sources in regard to the origin and degree of novelty.

	Idea collection	Idea production
internal	Sales office reports	Idea competitions for employees
	Complaint reports	Company suggestion program
	Secondary results of company suggestion program	Analysis of products of competitors
	Sales and costumer statistics	Product application from employees
external	Patent research	Observation of end-users
	Observation of competitors	Consulting experts
	Exhibitions	Market research
	Reports of research institutes	Contacts to leading suppliers

Figure 2.13: Methods of idea finding (Seibert 1998, p. 162; Pepels 2004, p. 390)

Idea suggestion

The evaluation and preliminary selection of ideas has the aim of developing the obtained ideas into rough product concepts and to select the proposals which are most promising to the company (Seibert 1998, p. 165).

The pre-selection of these ideas should be carried out by a group of experts, since a comprehensive market research at this time is too expensive. The company has to rely on the industry knowledge of the group members (Strunz & Dorsch 2001, p. 36).

Due to the high number of ideas, it is recommended to apply an initial screening with the aim of a search field-oriented selection. Thus, the high number of ideas can be reduced in the initial step (Vahs & Burmester 1999, p. 180).

Seibert (1998, p. 165) recommends, if after this screening, a lot of ideas still remain, using a step-by-step scoring system for idea selection, in which the keenness of the criteria and the scope and depth of information increases gradually, dependent on the concrete selection level.

2.5.2 Idea acceptance

The phase of idea acceptance includes the sub-activities of idea examination, preparation of realization plans, and decision for a realisation plan (Thom 1980, p. 79). The goal of this phase is a comprehensive investigation of the consequences that would result from the implementation of the idea and subsequently, to decide on one or more ideas that will be realised (Heesen 2009, p. 68).

Examination of the idea

After completion of the idea generation and pre-selection, detailed technical and economical concepts of the remaining ideas have to be developed and subjected to a performance audit. The results are then summarised in a business plan which serves as the basis for decisions regarding the realisation of an idea (Seibert 1998, p.168).

To develop these concepts, appropriate assumptions have to be taken about parameters such as future sales, volume, price, and the behaviour of competitors. This requires concrete experience. A systematic and methodical procedure is also crucial for guaranteeing that all relevant criteria are fully and comprehensively considered (Vahs & Burmester, 1999, p. 182).

Preparation of realisation plans

The planning of the idea implementation follows the evaluation of the ideas. The general question is, ‘which steps must be planned so that the idea has the highest possible chance of acceptance and implementation?’ In this regard planning requires thoughts on future actions to achieve desired goals using the resources available (Disselkamp 2012, p. 187).

Decision for a realisation plan

In literature, evaluation and decision for a project are often grouped together. Vahs & Burmester (1999, pp. 119-220) point out, however, that separation is appropriate since the assessment and the decision is usually not made in the same instance. In fact, in most cases, the top management is responsible for the decision of the implementation of a product idea. If the evaluation results are conclusive, top management typically follows the recommendation. If this is not the case, fundamental decisions mainly based on experience must be made. The solutions that are not selected for implementation are not automatically disabled and can still be reconsidered at a later point in time.

2.5.3 Idea realisation

The third phase of the innovation process deals with the concrete realisation of the idea, the sale of the product on a proper market and the control of the acceptance of the users.

Concrete realisation of the idea

Product concepts that have been identified as attractive due to a profitability analysis and business planning will be forwarded to the research and development department. The concepts are then transformed from the paper stage into manufacturable and marketable products. Thus, a steep rise in expenses and tight deadlines are the result (Seibert 1998, p. 174).

Disselkamp (2011, pp. 211-213) points out that the implementation phase is time comprehensive and critical for the future innovation success. During the realisation phase, it shows whether or not the planning and preparation were competent and goal-oriented. Up to 80% of the projects fail in the realisation phase. However, reasons for the failure usually originate in earlier stages. According to Disselkamp, the main reasons for failures include the inadequate integration of all involved persons, inadequate project planning and a lack of project management and controlling.

Basically, the product development takes place in several (usually two to three) draft-construction testing cycles (Figure 2.14) building upon each other. In the initial step, the design goals are set and technical problems are defined. Ideas for solutions to these problems are researched and developed. In the next step, models for tests and experiments are built. If the tests provide satisfactory results, the development has been completed. If not, the whole cycle repeats itself. With increasing repetition, the duration of such a cycle typically becomes shorter (Seibert 1998, p. 174).

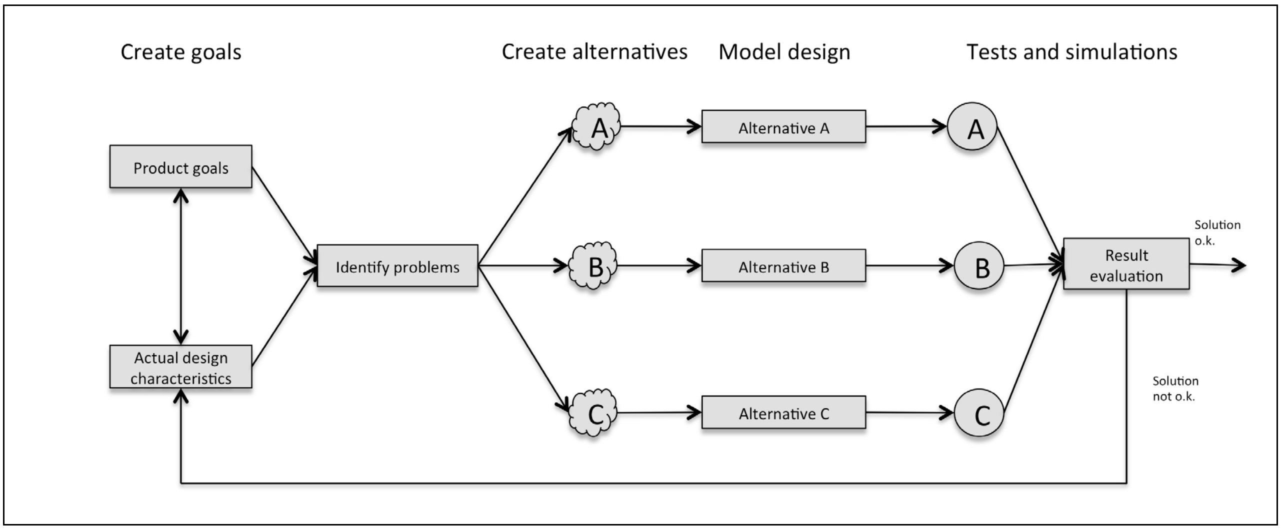

Figure 2.14: Draft-construction testing cycle (Seibert 1998, p. 175)

Sale of the idea to an addressee

The launch of a product covers the period from the beginning of the preparatory actions for market entry to the achievement of a stable revenue growth. Often the breakeven point is defined as the end point of the introduction period (Meffert 1998, p. 330).

After completion of all tests so that the risk of failure is largely excluded, the product can be introduced. In addition to the marketing, technical issues like the ramp-up of the production, the teaching and retraining of workers and the performing of trial runs to test the production facilities also have to be taken into account. In this phase, intensive quality management activities are needed to keep the start-up costs low. Diffusion research shows that various marketing measures like advertising, personal selling, or an offer of conversion must be applied in order to stimulate customers for purchase, since in general, only a few clients hesitantly buy innovative products. The literature distinguished between five customer groups (Seibert 1998, pp. 176-178):

- *First time buyers*: Innovative people with willingness to take risks.
- *Early adopter:* Informed people, opinion leaders.
- *Early majority:* Cautious buyers who wait for the opinion of the early adopters.
- *Late majority:* People who buy a product only if the majority has already accepted it.
- *Latecomers:* Conservative people who oppose changes.

In order to succeed, it is crucial to reach first-time buyers and early adopters. In turn, this can greatly accelerate the enforcement of an innovation (Seibert 1998, p. 178).

Control of acceptance

Controlling during the launch phase is an important process that has not been taken into account yet. At the beginning of the development process, assumptions about the life cycle are made. These assumptions are also elements of the business plan which, however, can only be created with the help of projections. Once the product is on the market, much more detailed and precise data is available which can be used to update the business plan, since between the beginning of the development and market launch internal and external conditions may change significantly. These changes have essential influence on the success of a product. At this stage the product's success and the factors that determine this success have to be controlled. Thus, the increase in value throughout the product life cycle can be controlled to a certain degree and the development of follow-on products can be initiated in time (Schäppi et al. 2005, p. 21).

2.6 Summary

Chapter two provides a theoretical overview regarding ‘Innovation’ and ‘Innovation Management’, examined during the research phase of the thesis. It primarily serves the reader for better understanding of the practical part, which builds on the theoretical part. The definition of the concept of innoation, innovation management and innovation strategy creates a consistent base. The clarfication of types, characteristics, driving forces, impediments and success factors of innovations is important in order to reduce the probability of failure during the practical part.The Model by Thom is chosen as a framework with the main focus on the phase of the idea acceptance, since it is clearly structured and has been successfully applied in the past. Next to a sound definition of the Model by Thom the Cooper and the Brockhoff Model are described to make comparisons possible.

3 Shape Memory Materials

In addition to knowledge about Innovation and Innovation Management (described in Chapter 2), it is important to understand the functioning of Shape Memory Materials, which are used for MASA. Shape Memory Materials (SMM) have the ability to memorise a certain shape and change it on demand, triggered by external stimuli such as heat, light, magnetic fields, or electricity. Three main groups, Shape Memory Polymers (SMP), Shape Memory Ceramics (MSC) and Shape Memory Alloys (SMA) can be distinguished.

3.1 Shape Memory Polymers

Basically two types of Polymers actively changing their shape are mentioned in Literature: Polymers with Shape Memory Effect (SME) and Polymers with Shape Changing Capability (SCC). The basic molecular structure is the same, but the mechanism initiating the active movement differs (Lendlein & Behl 2010, pp. 3-4).

3.1.1 Shape Memory Effect in polymers

With the application of external stress, SMP can be fixed in a temporary shape until being exposed to a trigger such as heat or light. The material then reverses the mechanical deformation in the same way it was created. This is the so-called SME. Besides the reversibility of the process, the transition also causes changes in mechanical properties, for example, Young's Modulus. Two important indicators of this SME are the shape fixity ratio (R_f) and the shape recovery ratio (R_r). R_f describes the ability of the material to fix the temporary shape, while R_r represents the ability of recovery. SMP are lightweight and allow substantially higher elongations than SMA. Additionally, the easy process ability and low costs compared to SMA are advantages. However, the relatively low recovery stress of SMP (3±2MPa) compared to SMA limits their application potential. Another significant disadvantage of SMP is the relatively high temperature change when heat-triggered. Light-Induced SMP are closing this gap, but have poorer ratios of R_f and R_r compared to heat-induced SMP. Nowadays SMP are used in many fields like packaging, electronics, textiles, and sophisticated aerospace or biomedical applications (Lendlein & Behl 2010, pp. 3, 5, 9, 25 & 46).

3.1.2 Shape Changing Capability in polymers

Unlike SMP, Shape Changing Polymers (SCP) change their shape when exposed to a certain stimulus and recover once this stimulation is terminated. This process can be reversed several times. Light, heat and magnetic fields can serve as stimuli. With thermo sensitive SCP, a relatively high reversible deformation potential within a narrow temperature interval can be investigated. Triblock copolymers, for example, can even reach shrinkage of 470%. Light sensitive SCP show a relatively low shrinkage of 0.1% to 20% with long recovery times from 1 minute to 90 minutes when exposed to light (wavelength around 400nm). Potential applications can be found in many areas like active medical devices or thermally induced textiles, which have already reached the mass market (Lendlein & Behl 2010, pp. 25-35).

3.1.3 Shape Memory Polymer composites

By adding micro/nano-sized fillers to the polymer matrix, the properties of SMP, such as modulus, strength, stiffness and recovery stress, can be dramatically improved. Moreover, the incorporation of fillers makes it possible to implement new functions like inducing active movements by different external stimuli, for example, alternating magnetic or electric fields. This method of actuation is very crucial when a direct thermal actuation is not possible (Lendlein & Behl 2010, pp. 44 & 91).

Table 3.1 shows different characteristics of Shape Memory Polymers and Shape Memory Gels compared with Shape Memory Alloys.

	Shape Memory Polymers	**Shape Memory Gels**	**Shape Memory Alloys**
External stimuli	Temperature, pH, light	Temperature, ph, light, chemicals	Temperature
Change of hardness[3]	Hard-soft	Hard-soft	Soft-Hard
Response time	Several s order	Several s order	ms order
Recovery force	1kg/mm^2	--	Several tens kg/mm^2
Recovery ratio	400-500%	400-500%	8%

Table 3.1: Key figures of Shape Memory Polymers and Shape Memory Gels compared to Shape Memory Alloys (Otsuka & Wayman 1999, pp. 120-122; Kajiwara 2001, p. 374)

3.2 Shape Memory Alloys

In 1951 scientists investigated two unique properties in a certain alloy[4], which ordinary alloys and metals do not have: The Shape Memory Effect and the Superelasticity (Otsuka & Wayman 1998, p. 2). Both phenomenons are based on the same origin called Martensitic Transformation. Martensitic Transformation changes abruptly the

[3] Change of hardness from low to high temperature
[4] Scientists investigated a Gold based Alloy with a high content of Cadmium (Au-47 at% Cd).

austenitic to a martensitic lattice structure of an SMA when the temperature is falling below a critical temperature (martensite start temperature). Although the distortion is quite significant, there is no diffusion and no relative change in position of the atoms. The martensitic structure changes back when exceeding another critical temperature (austenite start temperature). Therefore, Martensitic Transformation is reversible (Bhattacharya 2003, p. 4).

The transformation of austenite to martensite and vice versa, martensite to austenite, happens at different temperature levels (Stöckel 1988 et al., p. 47). Figure 3.1 shows a typical hysteresis:

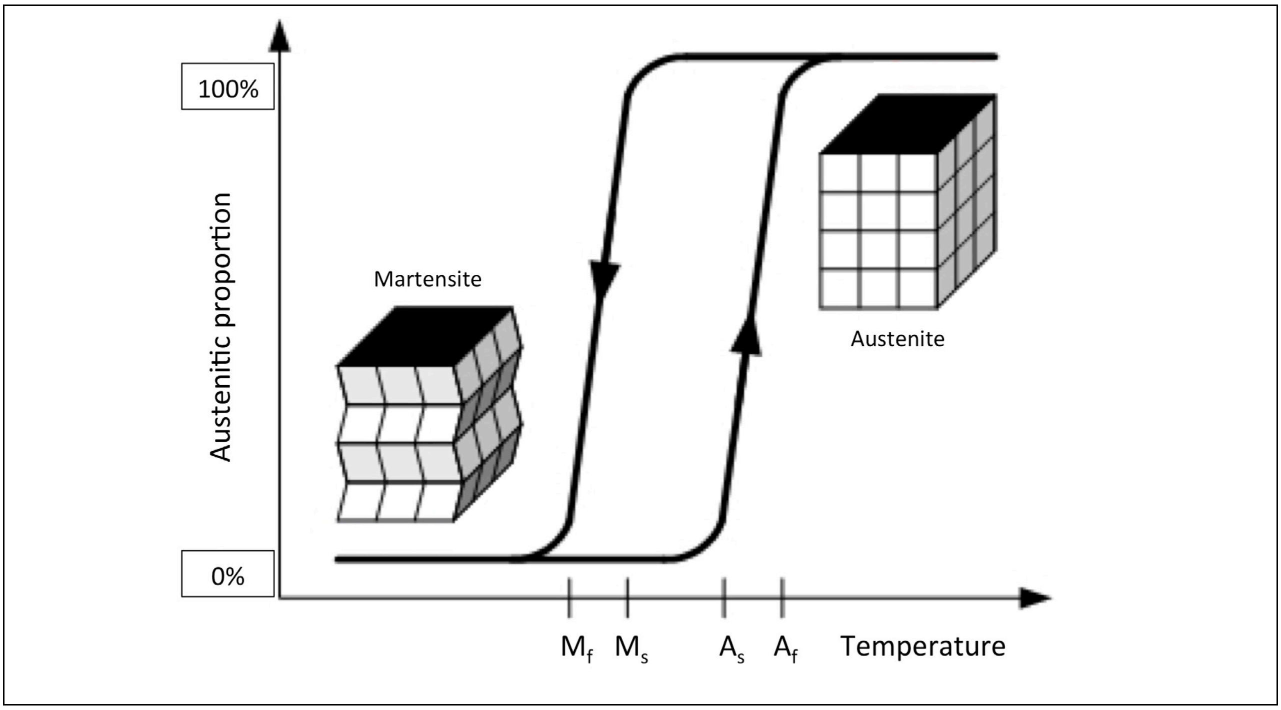

Figure 3.1: Hysteresis of a Shape Memory Alloy (Stöckel et al. 1988, p. 34)

3.2.1 Super-elasticity

Super-elasticity is a phenomenon that occurs usually above austenite finish temperature. The normally stable austenite changes to stress-induced martensite which is only stable under stress. A so-called martensitic plateau can be observed when stress is applied (Otsuka & Wayman 1998, p. 28). The martensitic plateau leads to an elasticity area of up to 8% strain that follows the usual elasticity after Hooke (Stöckel et al. 1988, pp. 62-63). The Hooke Elasticity is characterized by a proprtional stress and strain curve (Issler & Häfele 2003, p. 137). For example, springs with a constant force that is independent from elongation can be identified appling this effect (Stöckel et al. 1988, pp. 62-63).

3.2.2 Shape Memory Effect in alloys

SMA can be deformed below austenite start temperature and regains its original shape when heated to a temperature above austenite finish temperature as long as the strain does not exceed a critical value.

Figure 3.2 describes this process: Picture 'a' shows a deformed specimen below austenite start temperature. Once the specimen is heated above this temperature, martensite starts to transform into austenite. Since there is no diffusion and relative change in the position of the atoms, the specimen will regain its original shape once the temperature is above austenite finish temperature (pictures 'b-e'). Without applying any stress during cooling of a SMA below martensite finish temperature, the structure changes to martensite, but no change of the shape can be observed. The martensite restructures itself (self-accommodated martensite) by slipping or twinning (picture 'f'). The specimen can be deformed again (Otsuka & Wayman 1998, pp. 26-36).

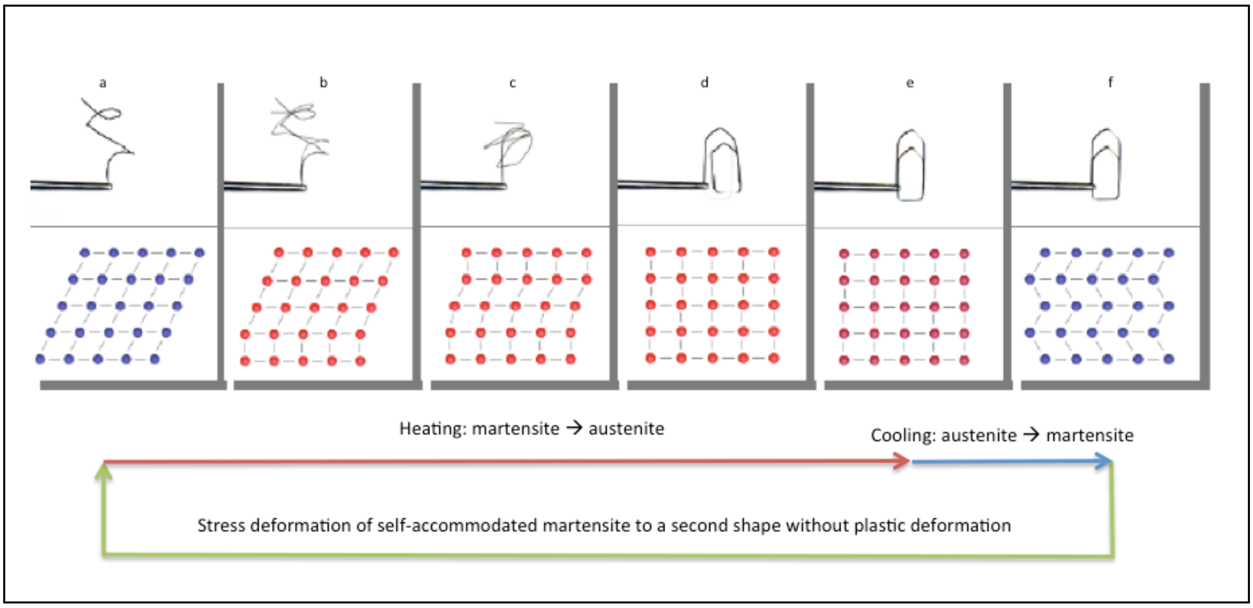

Figure 3.2: Shape Memory Effect (Srtittmatter n.d., p. 6)

The martensitic transformation is also known from strengthening steel, where a high volume difference between martensite and austenite induces high internal stresses that in turn create an irreversible deformation. Therefore, a prerequisite for SMA is a small volume change between the two phases (Stöckel et al.1988, p. 31).

3.2.3 Two-way memory behaviour

Chapter 3.2.2 explains the classical one-way memory behaviour. The material remembers the initial shape and changes back when heated above a certain temperature. However, the material does not remember the deformed shape and maintains the initial form after cooling as long as no force is applied. Two-way memory behaviour remembers two shapes, one at low temperature and another one at a higher temperature. In order to achieve this special behaviour, a special thermo-mechanical treatment is needed: the so-called education of the material (Auricchio et al. 201, p. 115). After the treatment, the SMA ‘remembers’ both stages without the need of any restoring force. The achievable elongation, however, is lower.[5] As well as this real two-way memory behaviour it is possible to create pseudo two-way memory behaviour. A constant restore force (for example a spring) that is strong enough to deform the martensite but too weak to deform the austenite significantly, can be used to obtain this behaviour (Stöckel et al. 1988, pp. 40 & 41).

3.2.4 Applicable alloys

At present only NiTi, Cu-Zn-Al and Cu-Al-Ni alloys are suitable for technical applications (Stöckel et al. 1988, p. 74).

NiTi-based Shape Memory Alloys

NiTi alloys with a nickel content of about 50% (atoms) are the most common alloys in technical applications. The transformation temperatures of this alloy range from -100 to 120 degrees Celsius (°C) and can be adjusted by adding other elements like copper or iron. Moreover, external stresses influence the reverse start transition temperature. It rises between 10 to 20°C if an external stress of 100 N/mm^2 is applied. The width of the hysteresis of NiTi lies at about 30K and can be reduced down to 4K with the addition of copper. The two-way memory behaviour of NiTi alloys is heat resistant up to 400°C. NiTi alloys exhibit excellent results in terms of memory behaviour. A non-plastic deformation of a maximum of 8% is possible. Moreover, NiTi based SMA show good properties in strength, resistance to corrosion and ductility. However, the relatively high price compared to copper-based SMA is a significant disadvantage (Stöckel 1988, pp. 42-76).

Copper-based Shape Memory Alloys

The price, electrical and thermal conductivity are advantages of copper-based SMA. Moreover, with less than 10K they have a very narrow hysteresis but exhibit significant lower memory behaviour. Another disadvantage is the low effect stability and the low permissible stress compared to NiTi Alloys. Copper-based SMA resist at maximum 10000 cycles with 10% loss of effect, while NiTi-based SMA endure 100000 cycles with practically no degradation (Stöckel 1988, pp. 42-76).

---

[5] NiTi SMA with one-way behaviour show elongations till 8%, whereas the same alloy with two-way behaviour allows elongations up to 5%.

Table 3.2 shows property values of SMA that are important for election and design for technical applications. It should be noted that the table shows experimental investigated values. The values in real-life applications can be significantly lower.

Property value	Unit	NiTi	Cu-Zn-Al	Cu-Al-Ni
Thermal conductivity	*1/Wm*K*	10-18	120	30-75
Corrosion performance	--	Similar to 300 series stainless steel	Similar to aluminium bronzes	Similar to aluminium bronzes
Yield strength austenite	MPa	100-800	350	150-300
Yield strength martensite	MPa	50-300	80-300	150-300
Ultimate tensile strength	MPa	800-1500	400-900	500-1200
Fatigue strength after 10^6 cycles	MPa	350	270	350
Shape memory transformation temperatures	°C	-100 to 120	-200 to 120	-200 to 200
Hysteresis	°C	4-120	5-25	20-40
One-way memory strain	%	8	6	5
Two-way memory strain	%	5	4	2
Maximal recovery stress	MPa	600-900	500-700	300-600
Maximum temperature[6]	°C	400	160	300

Table 3.2: Property values (Otsuka & Wayman 1999, p. 120-122)

[6] Maximum temperature that can be applied for one hour without destroying the structure.

3.3 Shape Memory Ceramics

A very similar effect to the martensitic transformation can be observed on ceramics. During the so-called ferroelastic phase transition the initial paraelectric phase changes during cooling to an antiferroelectric phase. The antiferroelectric phase shows similar behaviour to SMA. After deformation and heating, the material is able to restructure the initial shape. In general, SMC actuators have a very good response time and need less drive energy than others, but the very little strains are a significant disadvantage (Otsuka & Wayman 1998, pp. 184 & 185). Since strain will be a key factor in the success of this work, no further details will be investigated.

3.4 Summary

All materials, SMP, SMA, and SMC have some outstanding characteristics. Polymers show enormous deformation rates, ceramics can be directly stimulated by electricity and alloys create outstanding forces. Nevertheless, the generation of high forces and a minimum non-plastic strain is essential and therefore ceramics and polymers drop out. Only alloys seem to be able to generate enough force over a high number of cycles. The relatively small deformation rate compared to polymers is a disadvantage and will be a critical point in this work. Moreover, NiTi seems to be the most promising alloy, due to the high strain and good cycle stability compared with other copper based alloys.

4 Mechatronic Adjustment System Automotive

The theoretical part provides the reader with knowledge about the topics innovation, management of innovation and shape memory materials in order to facilitate the understanding of the practical part. The practical approach, in turn, deals with the evaluation of the technical and economic feasibility of Mechatronic Adjustment System Automotive (MASA) embedded in the major phases of the Thom Model. An introduction describes the idea in order to create a base for the reader. The idea generation phase was already completed before starting the thesis and will be described briefly. The subsequent step examines the feasibility of MASA for applications in car seats. In order to conduct the feasibility study and to apply analysis tools to MASA, the field of application was narrowed down to a specific application, a lumbar support adjustment system. This makes it possible to compare values of similar, already existing products and the new technology. Since MASA cannot just be used for car seat adjustment systems but for any adjustment in a car, the work points out additional application possibilities based on the acquired knowledge. The idea realisation phase is not part of this work. However, the last part of this chapter briefly discusses recommendations for this phase.

4.1 Idea generation

Generating ideas is the first stage of the innovation process, which was carried out in advance. In other words, this phase was completed before the start of the thesis and MASA is one of those ideas that passed this stage. Besides the determination of the search field, this phase contains the collection of ideas and the subsequent following idea rough-selection.

4.1.1 Determination of search field

Magna International names six promising search fields for innovation. These strategic fields (Figure 4.1) are meant to be a guideline and stimulus regarding the creation of innovations based on the know-how of the company and attractive market segments. Innovation projects conducted by the company should cover at least one of these fields.

Figure 4.1: Innovation search fields of Magna International (own illustration)

The exclusion of gearboxes and electric motors should allow a significant size reduction. This in turn, leads to more space for the passengers. It is particularly true for luxury cars where the installation of even more than ten electric motors per front seat causes significant space problems and a reduction of comfort. Additionally, this exclusion should lead to a reduction of weight. Since MASA matches with two of the six strategic innovation fields of Magna International Inc. (comfort and convenience as well as light weight), it is to be assumed that the project goes in the right direction.

4.1.2 Idea generation and collection

The generation of a large number of ideas is an important necessity in the innovation process, as most of the generated ideas will be ruled out in the course of the process. To ensure a successful generation, many tools were developed as explained in chapter 2.5. However, Magna decided to establish the WIN program to supplement these traditional tools.

The WIN initiative has become a worldwide program and aims, whether clerk or production staff, to reach all employees of Magna. In order to publicize the WIN initiative, relevant information was distributed to the leaders of the different groups and areas. Additionally, folders were designed and articles were published in the employee newsletter. To collect as many ideas as possible, submission by mail, fax, email or internet was possible. In order to answer any questions regarding the initiative quickly and effectively, a hotline has been set up that can be reached for free. All submitted ideas are saved in a database that represents the pool of ideas. After successful submission, the employee receives a notification that the idea is being processed. The employee can view the status of his idea at any time in the intranet (Winning Innovations Website, 20.4 2013).

4.1.3 Rough selection of ideas

Every idea in the idea pool is pre-filtered with respect to certain exclusion criteria (for example: already published, not legally possible, etc.). If there is any exclusion criterion, the idea will be forwarded to specialists. These specialists evaluate the idea in terms of market potential, feasibility, innovativeness (novelty factor), patentability, profitability, risk assessment and the specific attractiveness for Magna. The most promising ideas will be forwarded to the WIN jury for a final evaluation. The jury is composed of experienced professionals from various Magna groups and functional areas. Figure 4.2 shows the above described selection process (Winning Innovations Website, 20.4 2013).

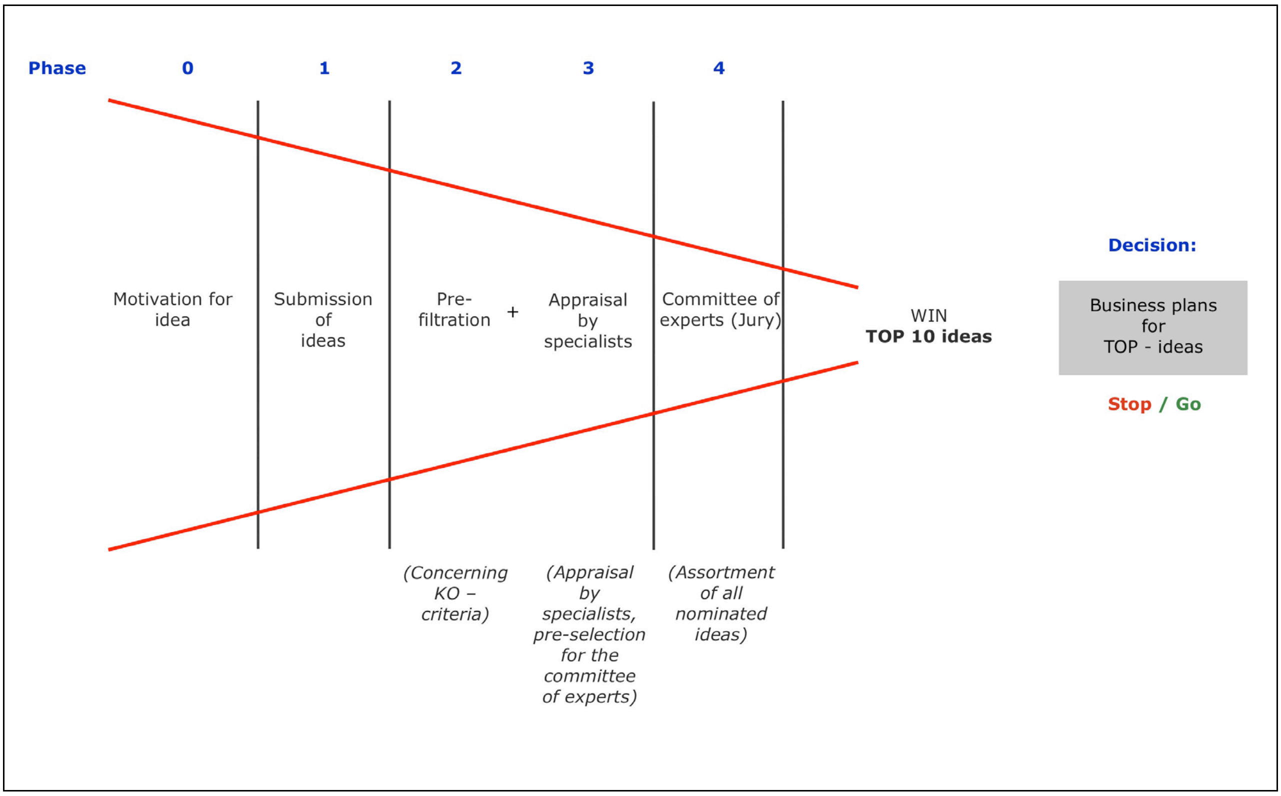

Figure 4.2: WIN selection funnel (referring to an internal source of Magna)

4.1.4 Detailed description of the idea

The idea is to use the special properties of Shape Memory Alloys in Car Adjustment Systems and called it Mechatronic Adjustment System Automotive (MASA). Especially Nitinol, a nickel titanium alloy, has promising material properties. Nitinol can change its shape on demand even under high load. The shape changing effect reacts on temperature changes, but can also be triggered by electricity. The application of this alloy makes the realisation of targeted longitudinal movement and torsion possible. Thus, it enables the substitution of traditional adjustment systems using gearboxes and motors or other actuator systems. The use of the technology should produce clear benefits regarding the weight, the space consumption, the noise or the cost situation. At best, the application of the technology brings advantages for all mentioned criteria.

Additionally, adjustment systems with SMA offer a high variety of application possibilities:

- Seat adjustment system
- Mirror adjustment system
- Window lift
- Locking mechanism for car doors
- Sliding roof mechanism
- Ventilation flap adjustment system

However, the first intention is to use the technology for a lumbar support adjustment system, since some of the project members are already familiar with the state of the art technology in this area. A second reason is, that Magna Seating shows interest especially for this application.

Conceptual model

Simultaneously to the feasibility study, the project team worked on a conceptual model to proof the functioning and to visually present and explain the product idea. This conceptual model is designed for a small seat model that was provided by Magna Seating. At a later stage, a prototype will be constructed, which can be installed in a real car seat. With this prototype, Magna Seating will be able to present the product to various OEMs, at an early stage.

The conceptual model consists of a frame, two springs, screws for fixation, two rods to guide the paddle, two clamps, the paddle and an SMA wire. This wire is heated by an external power supply. For the first experiments, the control is a simple potentiometer. By heating the wire above a certain temperature it contracts due to the SMA effect. This contraction, in turn, exerts a force on the lower ends of the paddle and deforms it in a way that it results in a deflection. This deflection presses on the back of the seat and represents the lumbar support adjustment. The deflection cannot be regulated yet, due to the simple control. Key findings from literature and construction are that the wire cannot be soldered or welded but has to be clamped (the high temperature during the soldering would substantially influence and destroy the properties of the alloy).

The model achieves a deflection of 8mm. Projected to a normal seat, it means 4cm of deflection. At present, lumbar adjustment systems require an adjustment range of 2.5cm. It can therefore be assumed that no problems regarding the expected deflection will occur. One reason is that the wire can exert tremendous forces and thus the adjustment can be extended by a lever construction. This prototype currently only represents a two-way lumbar adjustment system. However, the adjustment device is height-adjustable and the prototype can be extended to a four-way lumbar adjustment system, by using either a conventional technology, or the MASA technology. Figure 4.3 shows the conceptual model.

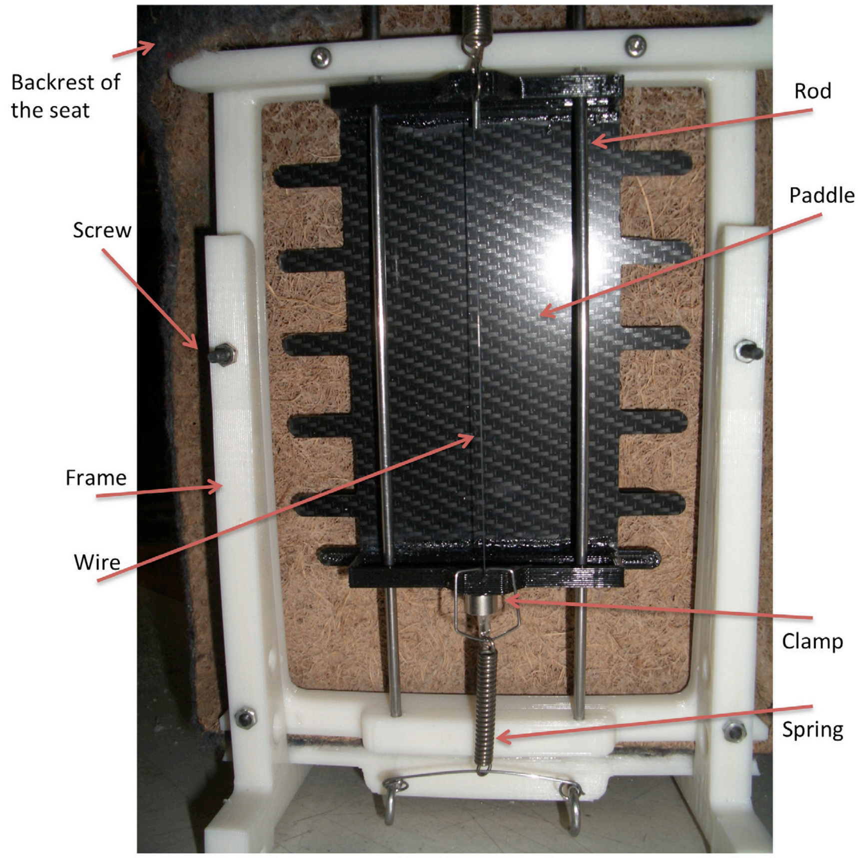

Figure 4.3: Prototype one (referring to an internal source of Magna)

4.2 Idea acceptance

The second phase of the innovation process by Thom contributes to the acceptance of the selected idea. It aims to reduce the potential for conflict by means of a feasibility study. At the beginning MASA is treated as a technology that is applicable in the entire car. Additionally, an application in other industry sectors is conceivable. The focus is on the replacement of a conventional drive unit by MASA and the associated increase in performance or even lower prices. In the course of the work however, a limitation is recommended that refers to a lumbar support adjustment system in order to make specific comparisons possible and to obtain more accurate analysis results. The restriction does not represent a particular disadvantage since the implementation of the idea based on the lumbar support adjustment system can be transferred to other projects. Based on the feasibility study, a business plan is created in order to represent the results of the study, in an easily understandable and transparent way for decision makers. The business plan is located in the appendix.

4.2.1 Swot Analysis

The SWOT analysis is one of the best-known analysis tools regarding strategic planning. It compares internal strengths and weaknesses of the research object with the external opportunities and threats from the environment. The acronym SWOT stands for strength, weaknesses, opportunities and threats (Simon & Gathen 2010, p. 230).

The aim of the SWOT analysis is to directly derive strategies for further action from the previously identified strengths and weaknesses. Specifically, the results of the SWOT analysis are entered in list-like form in a four-field matrix. Figure 4.4 shows a classic matrix of a SWOT analysis (Gelbmann et al. 2003, p. 13).

	List of weaknesses	**List of strengths**
List of chances	**Weaknesses-chances Strategies → *catch up***	**Strengths-chances Strategies → *boost***
List of threads	**Weaknesses-threads Strategies → *avoid***	**Strengths-threads Strategies → *secure***

Figure 4.4: SWOT analysis (Gelbmann et al. 2003, p. 13)

In the inner fields, the strategies can be derived from the corresponding dimensions by comparing each point of each field. Thus, four types of different strategy can be distinguished (Gelbmann et al. 2003, pp. 13-14):

- *Strengths-chances strategies* are used to utilise the strengths in order to take advantage of opportunities.
- *Strengths-threats strategies* serve to defuse possible outside threats, through the use of strengths.

- *Weaknesses-chances strategies* are used to reduce weaknesses in order to exploit opportunities.
- *Weaknesses-threats strategies* are used to reduce weaknesses in order to minimise risks.

The fact of the matter is that the strategies are more accurate and specific the better the individual strengths, weaknesses, opportunities and threats have been previously analysed and the more accurate the conclusions drawn are understandable. A disadvantage of the SWOT analysis can be, as with all strategic analysis tools, the necessary simplification of the observed object, that, in turn, influences the accuracy of the results in a negative way (Gelbmann et al. 2003, p. 13).

Usually, a SWOT analysis contemplates a company from an economic view. For this project the SWOT analysis is adopted in a way that also technical parameters are considered since the subject of valuation is a product innovation project and not a company. Therefore, the SWOT analysis can be seen as a basis to identify on the one hand, possible opportunities and threats which act from outside and on the other hand, product-depending strength and weaknesses related to MASA. The goal is to derive strategies for further action from these characteristics. In the initial step, an environmental analysis was conducted to find opportunities and threats which cannot be influenced by the project team or the product itself. Subsequently, an internal analysis portrays the strength and weaknesses of the product. Finally, strategies were created that serve as suggestions for further action for the management. The intention is to overcome threats and weaknesses on the one hand and to foster strengths and opportunities on the other hand. The results are derived from interviews with experts, the internet, patent research and a database (A2Mac1) that is used internally and includes exact information regarding weight, size and performance of seat parts various OEMs.

Opportunities:

a. *MASA will be accepted by the end-user:* The new technology increases the benefits for the end-user. It can be determined a high potential of acceptance, because existing problems like the lack of space and the noise that arises during adjustment operation can be solved.
b. *MASA will be accepted by OEMs:* Basically, all additional benefits recognised by the end-users can also be recognised by the OEMs. Additionally, the weight reduction and the easier assembly increase the acceptance. All seat producers speak nowadays of “Smart Seat Concepts”. In this respect the usage of “Smart Materials” seems to be adequate.

c. *MASA can be recognised easily by the end-user:* The noise reduction can easily be recognised. Especially in the case of the lumbar support adjustment system, the reduction of noise is easy to recognise because the system is placed relatively near to the ears of the user (In the case of the Audi A8 in the upper region of the backrest).
d. *Customers expect more features from car seats in future:* The use of the MASA technology offers a lot of possibilities for new or improved features in car seats. Our society longs for more comfort and applications in any situation of life. Regarding a car seat, the expansion of its functionalities is sometimes impeded by space problems. This opens possibilities for MASA to satisfy the demanding behaviour of the western society.
e. *Cooperation with innovative suppliers is possible:* Cooperation with the companies like Smarter Alloys and Memry is possible. Smarter Alloys invented a new technology to integrate, besides the traditional one-way and two-way behaviour, a multi-way SMA. This enables the realisation of incremental adjustment systems without difficult temperature control. After talking to a contact person from Memry it also turned out that the company is specialised in SMA based actuator solutions and already has experience in the automotive field. Moreover, cooperation with other suppliers like Dynalloy or Nimesis would be possible.
f. *A long life cycle of the technology is possible:* The technology replaces traditional actuators. If this does succeed, a long life cycle is to be expected. It will be difficult to find new solutions that reduce space and noise in the same way. Additionally, many functions in many application fields can be realised with this technique. The assumption of a long life cycle is also based on the fact that former systems, like the electric motor-actuator system, show long life cycles. Compared to other technologies, the development is rather slow.
g. *A potential market already exists:* The technology is especially interesting for the luxury car segment where the problems of space and weight play a central role and the noise reduction creates additional comfort. An application in modular seat systems is conceivable since the SMA actuator is adaptable to geometric changes (the cable can be deflected easily and yet exert a contraction). Additionally, the middle-class market is of interest in a further step when costs can be kept on an acceptable level.
h. *A market growth can be expected:* The MASA technology opens up a whole new range of applications that couldn't be realised yet. One idea is to develop a complex massage system with an SMA braid that can run complex movements across the entire surface of the backrest.
i. *The rather bad global economic situation has no big impact on MASA:* The technology will be used in a first step for luxury car applications. This market and, in

general, the automotive market is not in crisis at the moment. This can be explained by the fact, that the sales figures of all car classes have risen each year since the crisis in 2008 and 2009 and that they have by far exceeded the values of the pre crisis year 2007. Only the values of 2007 of class E have not yet been achieved.

j. *The automotive market can be entered easily:* Relations to potential OEMs already exist. These relations can be used to enter the market and create acceptance.
k. *The technology could be used for already existing projects:* Magna Seating has projects that focus on multi-functional car seats (Stow-in-Floor, Free2Stow) where flexibility is a crucial issue.

Threats

a. *Fulfilment of the technical expectations of the OEMs:* The technology has a lot of advantages but it is possible that some knock out criteria cannot be fulfilled. Such criteria are the minimum adjustment range (the adjustment range of an Audi A6 Premium Plus 3.0T is 21mm), the minimum force that can be applied (depending on the alloy composition, a maximum recovery stress of 300 to 900 MPa can be generated) or the minimum cycle number (a cycle number over 1.000.000 is possible but falling significantly when high recovery forces and high strain is demanded).
b. *Competitors create the same or even more benefits with other technologies:* Mainly, there are five competitors of relevance. Faurecia has a weight reduction program to reduce weight of seats targeted since it provides six to ten per cent of the total weight of a car. Furthermore, Faurecia sees seat adjustment systems as a core competence. The vision for the future is a “Smart Adjustment” system that adopts not only to the occupant, but also to the street conditions. Johnson Controls has the vision of a “Smart Seat” where the thickness is reduced significantly. Leggett & Platt is one of the world leading companies of comfort systems for seats. The company provides, among other technologies, massage functions based on pneumatic actuators. Leggett & Platt developed an Integrated Total Comfort Module. It provides a high level of comfort, outstanding adjustability, lower costs, and lower weight. The Lear Corporation focuses on weight reduction and renewable materials. The company invented a new decliner with a weight reduction of 35 per cent and a reduction in packaging size of 50%. Hyunday Dymos has, according to its own statements, the biggest research centre worldwide regarding automotive seats. One of their goals is it to set up new production facilities in Europe. It can be seen that several automotive seat producers focus on similar goals like weight, space and resource reduction. Therefore, there is a risk that one of these companies creates the same or a higher benefit with another technology.

c. *Competitors try to apply the same technology:* It is very difficult to find out, which innovations are planned by the competitors, but basically it seems that the competitors try to improve already existing systems to reach their goals. Nevertheless, a research on already existing patents revealed that companies like Faurecia or Sitech actively work on the application of SMA in car seats. Sitech, for example, registered a patent in 2010 for a longitudinal adjustment system for a head restraint. For this reason it is possible that a competitor has similar intentions.
d. *The suppliers cannot fulfil the technical expectations:* The literature shows that little deviation of the alloy-ratios can lead to a significant change in properties, like martensitic transformation temperatures. Additionally, no cooperation yet exists that would lower the risk of dissatisfaction.
e. *The protection with a patent could be problematic:* Companies like Sitech or Faurecia have already registered several patents regarding the application of SMA in car seats or car seat adjustment systems.
f. *Competitors will reduce the market possibilities:* As mentioned above several car seat producers are present on the market. The benefits created by MASA are mainly similar to the goals of the competitors. It may be expected that the market situation remains though (noise reduction could be the key benefit).

Strengths

a. *Weight reduction:* The new technology reduces the weight significantly. Lighter wires replace electric motors and gear mechanisms (a weight reduction of up to 35% is possible by replacing the conventional lumbar adjustment system of an Audi A8 with the MASA technology).
b. *Space reduction:* The width of the air chamber system used for an Audi A8 2013 is 31mm. With the new technology it is possible to reduce the width down to less than 10mm.
c. *Cost reduction:* The assembly is easier and requires fewer steps. The adjustment system consists of a small number of parts.
d. *Noise reduction:* The noise reduction represents a significant advantage since it is a main problem that can hardly be solved with a traditional motor-actuator system or any other mechanism.
e. *Functional reliability:* The use of a few robust components increases functional reliability (no valves, motors, actuators, bladders or tubes are needed).
f. *Simple and flexible design:* Complicated gear mechanisms do not have to be taken into consideration. Thus, the design is flexible and simple.

Weaknesses

a. *Difficult controlling:* The temperature interval between the transformation temperatures is very narrow (Figure 3.1). Additionally the environment has to be taken into account as a critical control parameter.
b. *Restricted adjustment range:* The MASA technology cannot be applied to high number of adjustment functions in a car seat due to the restricted adjustment range. This is especially true for adjustment functions with a large adjustment range where a lever mechanism may not be realised. The maximum strain that with SMA is 8% (this value cannot be reached in reality, due to the high cycle number and recovery force that is needed).
c. *Number of possible adjustment cycles:* The number of adjustment cycles, the applied force and the adjustment range are dependent from each other. Even though literature points out that over one million cycles are possible, high forces and a high adjustment range can significantly lower this number. This may not be a problem for a lumbar adjustment system, but a massage function requires more cycles than one million during its lifetime.
d. *Adjustment resets automatically when no electricity is supplied:* In case of electricity problems the system would not work.
e. *The produced heat affects the comfort of the end-user:* The heat produced by the hot wire cannot be removed and heats the backrest.

Figure 4.5 illustrates all opportunities, threats, strengths and weaknesses in one table.

Opportunities	***Threats***
a. MASA will be accepted by the end-user *b. MASA will be accepted by OEM's* *c. MASA can be recognised easily by the end-user* *d. Customers expect more features from car seats in future* *e. Cooperation with suppliers is possible* *f. A long life cycle of the technology is possible* *g. A potential market already exists* *h. A market growth can be expected* i. The rather bad global economic situation has no big impact on MASA *j. The automotive market can be entered easy* *k. The technology could be used for already existing projects*	*a. Fulfilment of the technical expectations of the OEM's* *b. Competitors create the same or even more benefits with other technologies* *c. Competitors try to apply the same technology* *d. The suppliers cannot fulfil the technical expectations* *e. The protection with a patent could be problematic* *f. Competitors will reduces the market possibilities*
Strengths	***Weaknesses***
a. Weight reduction *b. Space reduction* *b. Cost reduction* *c. Noise reduction* *e. Functional reliability* *f. Simple and flexible design*	*a. Difficult controlling* *b. Restricted adjustment range* *c. Number of possible adjustment cycles* *d. Adjustment resets automatically when no energy is supplied* *e. The produced heat affects the comfort of the end-user*

Figure 4.5: Opportunities, threats, strengths and weaknesses in regard to MASA (own illustration)

Strengths - chances strategies

a. Use the already existing relations with OEMs to launch the product.

b. Convince the OEMs of the significant advantages the technology has. Point out that the combination of noise reduction, weight reduction, cost reduction and space saving is achieved with this technology.

c. Incorporation of the end-user into the product development to create on the one hand acceptance, and attainment of additional input on the other hand. The adjustment movement will probably feel different. It is important to learn if this represents a strength or a weakness in the eyes of the customers.

d. Convince OEMs of the future potential of the technology in respect to the versatility. The technology can be used for many applications in car seats, the entire car, and other non-automotive areas.

e. Early incorporation of suppliers. Cooperation with Smarter Alloys or Memry seems to be adequate. Smarter Alloys' new multi-way technology could be used in future for incremental controlled applications, for example in middle-class cars or for the realisation of automatic adjustment systems in modular seat concepts like Stow-in-Floor. No complicated control system would be needed.

f. To enter the market concentrate on the luxury car market.

g. Try to incorporate the technology in already existing Projects. Future Forms is a seat innovation project that enables a thin profile and enhanced leg and knee room for rear seat occupants. The aim is to improve overall cabin spaciousness and allow the reduction of overall vehicle length without compromising occupant space, thus enabling significant mass reduction.

Strengths - threats strategies

a. Incorporation of the OEMs to avoid the risk of dissatisfied expectations.

b. Use the broad field of applications to lower the risk of ousting from the market.

c. Use the market potential in non-automotive areas even if the market entry is more difficult.

d. Fast patent registration to secure the rights for the technology. Differentiate the patent clearly from already existing patents. Conduct a thorough patent enquiry to make sure that the technology can still be registered as a patent.

e. Also use the technology for middle-class cars in order to enlarge the market.

f. Foster a fast development of the technology to avoid other competitors being faster. In the second step, strengthen the relations with the customers to make a market entry for followers more difficult.

Weaknesses - opportunities strategies

a. Use the knowledge of the supplier to solve possible problems with the control system or the design.

b. Clarify together with the supplier in an early stage whether the needed force-deflection-cycle number proportion is feasible or not. The supplier can provide hints on how to enlarge parameters by adequate design.

c. Find new applications for car seats, cars or other areas where an adjustment system with small adjustment range is needed in order to reap the full benefits.

Weaknesses - threats strategies

a. Do not make large investments before it is clear that the weaknesses can be kept under control.

b. Keep an eye on competitors. Are any of them launching a similar product? How do they overcome the weaknesses?

Figure 4.6 gives an overview over all strategies:

	Strength	Weaknesses
Opportunities	*a. Use of the already existing Relations with OEM's to launch the product* *b. Convince the OEM's of the significant advantages the technology has* *c. Incorporation of the end-user into the product development* *d. Convince OEM's of the future potential of the technology* *e. Early incorporation of suppliers* *f. To enter the market concentrate on the luxury car market* *g. Try to incorporate the technology in the Future Forms Project*	*a. Use the knowledge of the supplier to solve possible problems with the control system or the design* *b. Clarify together with the supplier in an early stage whether the needed force-deflection-cycle number proportion is feasible or not* *c. Find new applications for car seats, cars or other areas where an adjustment system with small adjustment range is needed in order to reap the full benefits*
Threats	*a. Incorporation of the OEM's to avoid the risk of dissatisfied expectations* *b. Use the broad field of applications to lower the risk of ousting from the market* *c. Use the market potential in non-automotive areas* *d. Fast Patent registration to secure the rights for the technology* *e. Use the technology also for middle-class cars to enlarge the market* *f. Foster a fast development of the technology to avoid those other competitors may be faster*	*a. Do not make large investments before it is clear that the weaknesses can be controlled* *b. Keep an eye on competitors. Are any of them launching a similar product? How do they overcome the weaknesses?*

Figure 4.6: Strategy options (own illustration)

4.2.2 Function analysis

Customers primarily procure their products and services at very functional aspects. They are willing to spend money on features that best meet their needs. Thus, the customer purchases rather the function and not the number of parts (VDI-Gesellschaft Produkt- und Prozessgestaltung 2011, p. 57).

For this reason, the functional analysis does not focus on the contemplated object but concentrates rather on the analysis of the functions of the object. A product can be made up by functions of different classes and types, which are shown in Figure 4.7 (Wohinz 1983, p. 31).

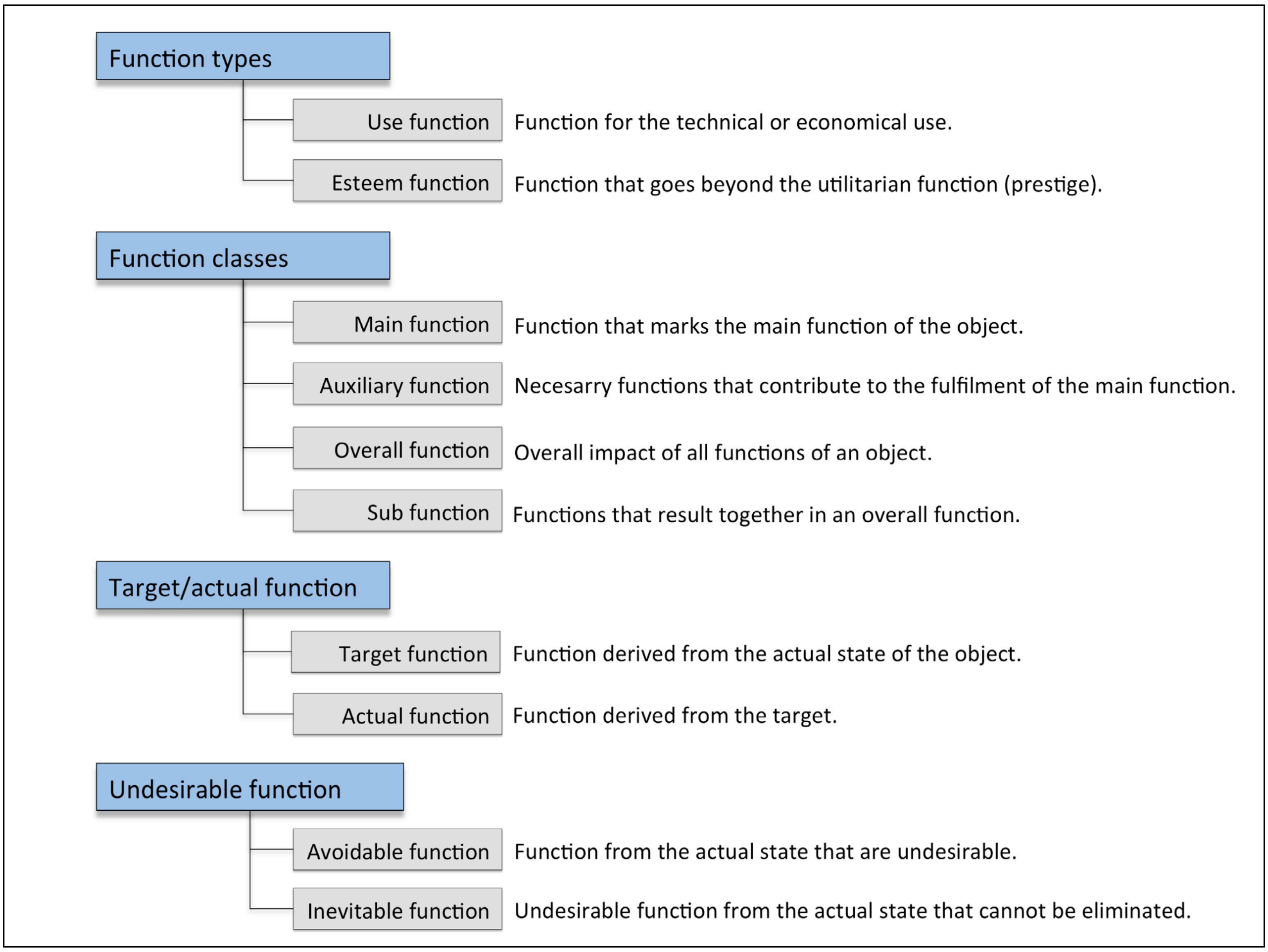

Figure 4.7: Function types (Wohinz 1983, p. 33; VDI-Gesellschaft Produkt- und Prozessgestaltung 2011, pp. 57-62)

With the description of functions, it is possible to break away from old-fashioned views and to concentrate on the effect a customer expects. Thus, the function analysis aims to bring the customers needs more into the foreground. The approach of this method is based on a three-stage model, which is described below (Gelbmann et al. 2003, pp. 46-47).

- *Understand the analysed object:*

An important foundation stone of a successful functional analysis is the correct and faultless recording of the analysis object. This includes a very accurate data collection. It is also important that all people involved have a common viewpoint on the object.

- *Name the functions:*

The naming of the functions through a quantifiable noun (effect carrier) and a verb (effect) is the core task of the analysis, in which the choice of the degree of abstraction plays an important role. In order to conduct a search for ways of further implementation possibilities, it is important to depart from the object. The aim is thereby to discard old thought patterns.

- *Structuring of the functions*

The functions of an analysis object cannot be seen in isolation but have mutual relationships. These relationships can be represented by means of a diagram. The function tree is the easiest to learn and is an understandable structure for beginners. The functions are assigned to different hierarchy levels.

Figure 4.8 shows a part of a Function tree with hierarchy levels and an example for an abstract naming of functions.

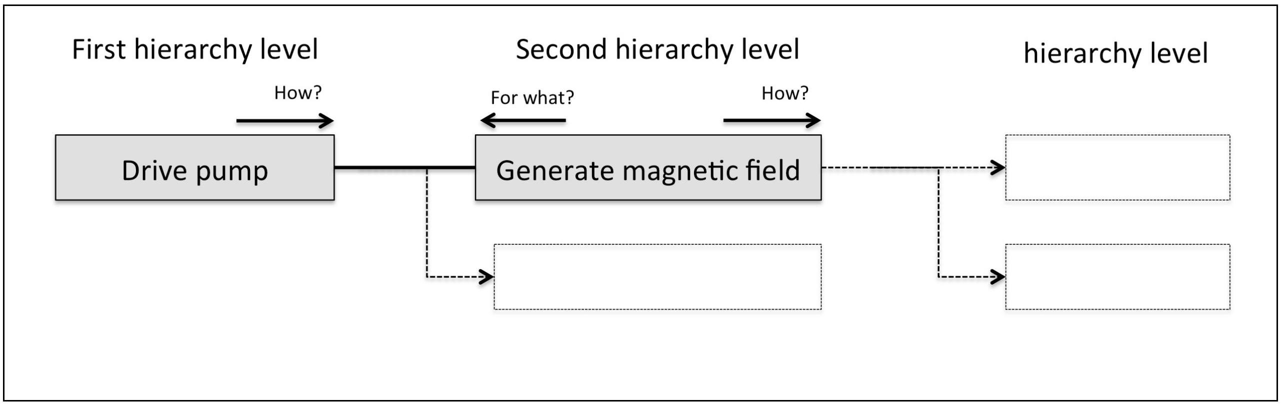

Figure 4.8: Example of a function tree (Gelbmann et al. 2003, p. 49)

Based on the function analysis, a cost-function matrix can be developed that examines the respective costs of each function. Subsequently all functions with high costs are analysed to either improve the functionality, to reduce the costs of the function or to remove the function if it is useless. This systematic approach can lead to unexpected cost reduction and higher functionality (Gelbmann et al. 2003, pp. 50-51).

Summarised, the function analysis describes all functions that have to be fulfilled by a MASA application. The aim is to provide, on the one hand, a basis for comparison of the idea with existing solutions and on the other hand, a description of the functions as abstractly as possible to not affect the implementation of the prototype too much. Another aspect is the patent application. All characteristics which result from the different functions have to be described accurately to achieve a high level of patent protection. Since MASA is an option for a variety of applications, it is difficult to undertake a general function analysis. Therefore, this function analysis is limited to a lumbar support adjustment for a car seat. Adjustment systems for other applications will be similar and this function analysis can be used as a starting point.

After collection of data on the object, all functions have been named with a subject and a verb. Figure 4.9 shows the structured links between the overall and sub functions. The sub functions can be derived from the overall functions by questioning “how?”. Accordingly, the auxiliary functions lead to the overall functions by questioning “for what?". In a last step this function analysis was discussed and improved in a workshop with all team members.

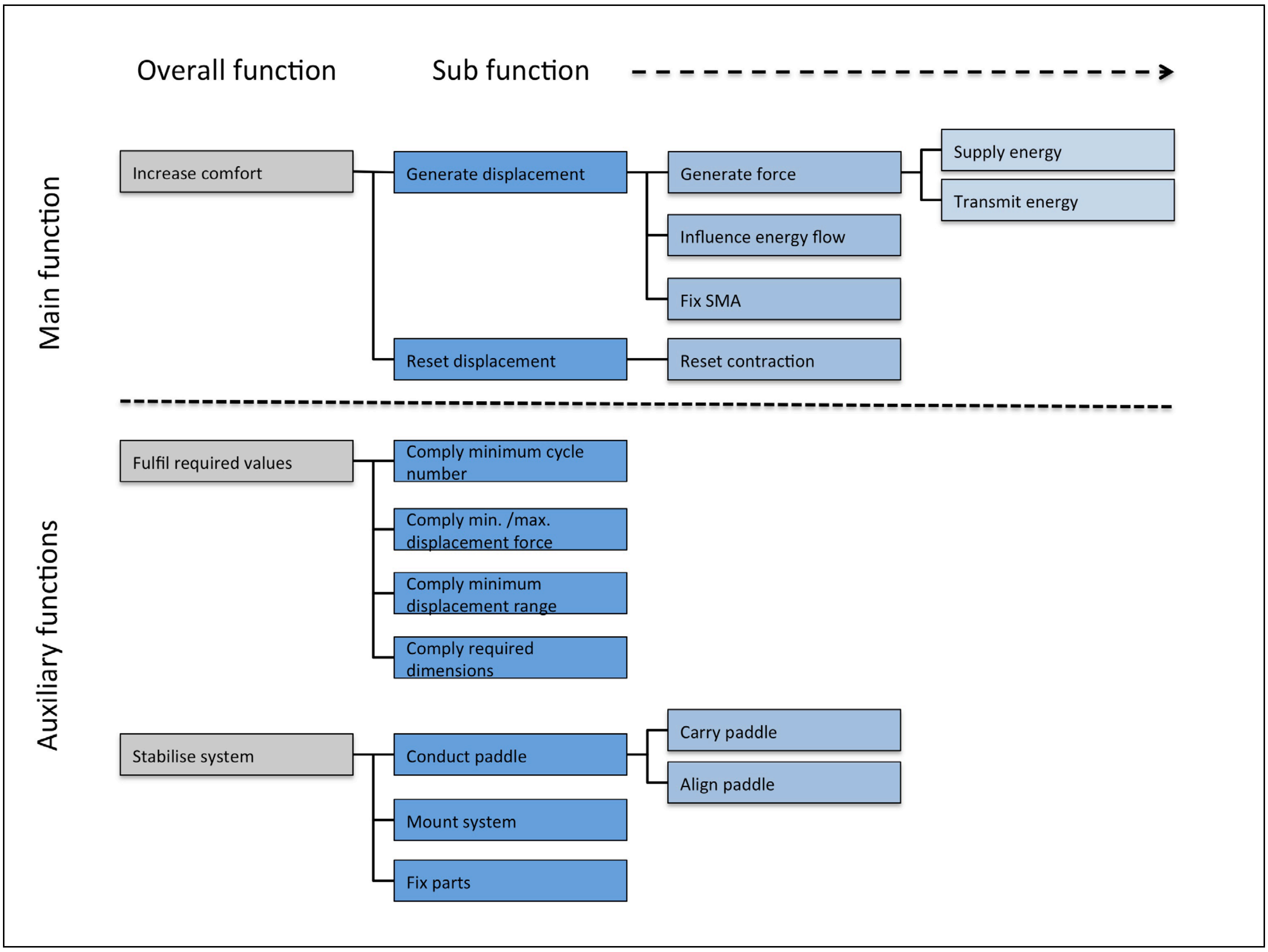

Figure 4.9: Function tree (own illustration)

Description of functions

1. *Increase comfort:* Lumbar support enhances occupant comfort by allowing the amount of lower back support to be adjusted.
   1.1. *Generate displacement:* The displacement is generated by the paddle (displacement device) and adjusts the form of the backrest.
      1.1.1. *Generate Force: SMA material generates great force when heated up.* The SMA doesn't necessarily need to be a wire. A rod, band or a plate could be the carrier of this function.
         1.1.1.1. *Supply energy:* An energy source is needed to supply heat generation. In the case of a car, the source is the car battery. For non-automotive applications, other energy supplies are possible (solar energy or electricity supply system).
         1.1.1.2. *Transmit energy:* The energy has to be transmitted from the source to the SMA alloy to generate heat. A classical approach is to heat the

wire up like a filament of an electric pulp. Another possibility would be an induction heat system.

1.1.2. Influence energy flow: A controlling system has to influence the energy flow to maintain a specific temperature. Figure 3.1 shows that only a small change in temperature already causes significant deflection.

1.1.3. Fixation of the SMA material: The SMA material has to be fixed at its ends to generate force.

1.2. Reset displacement: The displacement has to be reset on customers demand.

1.2.1. Reset contraction: By resetting the contraction of the SMA material force will be no longer applied on the paddle and thus return to idle position.

2. *Fulfil required values:* The lumbar support adjustment system must fit into the seat. Additionally, it must perform according to certain standards.

2.1. Comply the minimum cycle number: The lumbar adjustment system has to withstand a minimum cycle number set in advance by the OEMs.

2.2. Comply the minimum/maximum displacement force: The lumbar support adjustment system has to generate a force between a certain range set in advance by the OEMs and the law.

2.3. Comply the minimum displacement range: The lumbar support adjustment system has to generate a minimum deflection set in advance by the OEMs.

2.4. Comply the dimension requirements: The lumbar support adjustment system has to have certain dimensions to fit into the seat.

3. *Stabilise system:* Function carriers that stabilise the product are needed.

3.1. Fix parts: All parts apart from the displacement device have to be fixed in a certain position.

3.2. Mount system: The lumbar support adjustment system has to be mounted on the seat.

3.3. Conduct paddle: To enable an adjustable four-way lumbar support adjustment system, the paddle needs to be moveably mounted.

3.3.1. Carry paddle: The paddle has to be carried by a component that enables movement.

3.3.2. *Align paddle:* The paddle has to be aligned by components to set position either controlled by the end user (four-way lumbar adjustment system) or set by the producer in advance (two-way adjustment system).

4.2.3 Market analysis

Market analysis cannot be understood as a single method but it is much more a set of different methods, of which their results as a whole form an analysis. The market analysis provides information about the market prospects of the new product on the market, taking into account all market components. First, the structure of the supplier and the procurement market need to be examined. This is to determine whether the necessary raw materials and components for the production of the new product are available. Next, the client structure and the competitive structure are necessary in order to find out in which quantity, quality and under which conditions the new product can be sold on the market. Finally, all legal conditions should be checked to avoid any litigation costs and attorney fees. The market analysis provides the database for verification of the profitability and viability of the project and serves therefore as the basis for corporate planning as well as for external institutions with regard to the provision of capital (Witte 2007, pp. 42-43).

One of the main objectives of the market analysis is to formulate a target price for the product, which arises under the influence of the variables shown in Figure 4.10. Another key task is to limit the potential market. It is not so much the narrowing that is seen as the problem but searching for specific information is often difficult in practice.

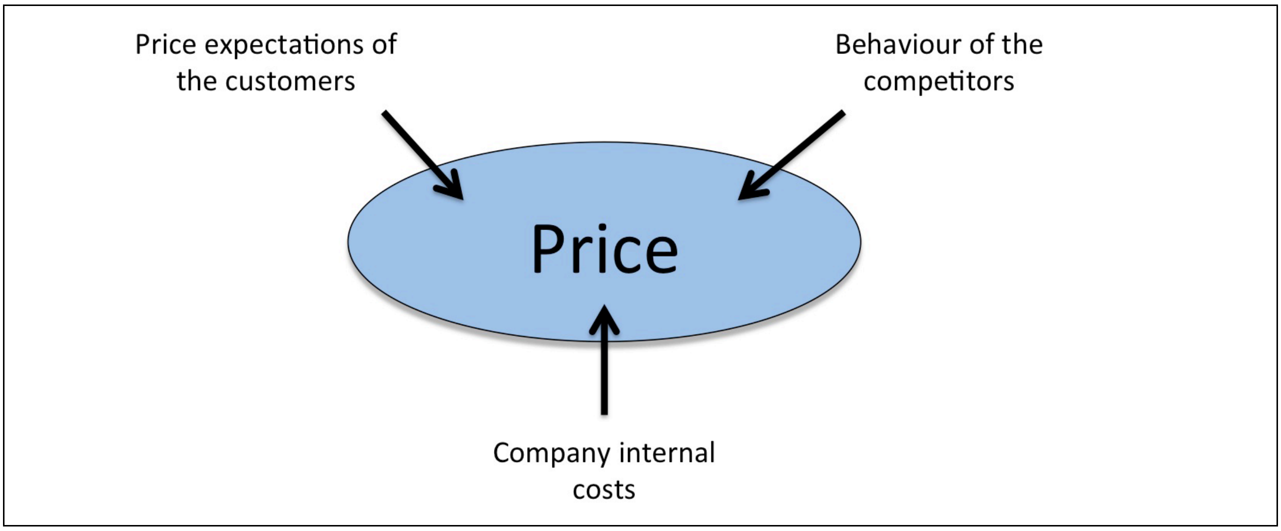

Figure 4.10: Price influencing factors (Gelbmann et al. 2003, p. 52)

Subsequently, all data obtained in the market analysis can be used for the presentation of a market life cycle in which all estimated costs are compared with the proceeds over time (Gelbmann et al. 2003, pp. 52-58).

The functional analysis provides a detailed and functional description of the idea (product concept). Subsequently the economic efficiency has to be questioned. The implementation of MASA only seems useful if a product advantage is available in sufficient quantities. Initially, the market analysis discusses competing systems that represent the direct competitors of MASA. In a second step, the market potential and customer segment for the market entry is determined. Finally the medium-term total market potential will be determined and demonstrated with sales figures.

Competing systems

To identify competing systems, expert interviews as well as a patent and internet research were carried out. Additionally information from the A2Mac1 database, an information platform that is used by Magna and contains information regarding seat components, refines the results. In principle, air chamber systems, manual systems and motor-actuator systems can be named.

Air bladder system: In such systems, the lumbar support is realised by an air bladder. The air bladder is connected to one or more hoses and a valve system. A pump supplies the system with air (it could also be any other fluid). The flow is controlled by the valve system. In many cases, the bladder that serves the lumbar support is just one of many bladders. All bladders can be controlled by the user separately, which leads to a large number of adjustment possibilities. The high number of components is a disadvantage (valves, pumps, pneumatic hoses, air cushion). Furthermore, the pump and the flow of the fluid cause noise. Currently, Faurecia, Legget & Platt, and Magna use the air chamber system. Johnson Control has filed patent applications that use such a pneumatic system. The air chamber system of an Audi A8 (model 2011) is illustrated in Figure 4.11 and Figure 4.12.

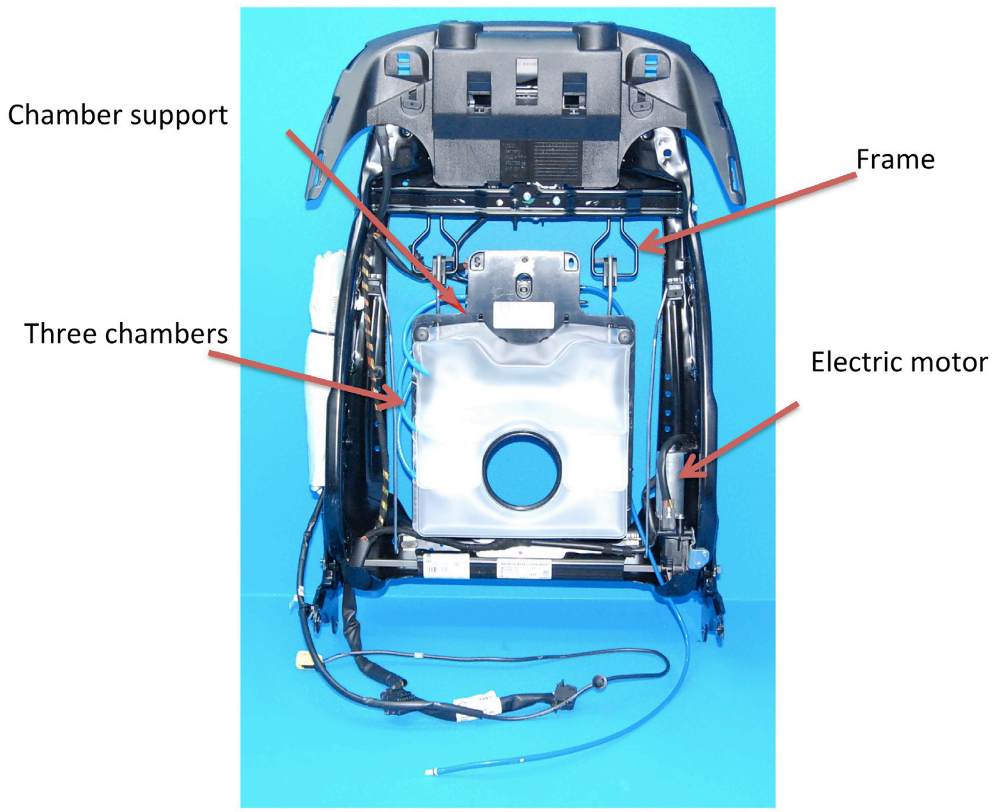

Figure 4.11: Air chamber system, front view (referring to an internal source of Magna)

Figure 4.12 shows the three separate chambers that create high adjustability. Furthermore, it shows the electric motor, the frame and the chamber support. The depth of this system is 31mm and can hardly be reduced, since the valve system creates additional width. The total weight including fasteners is 0.95kg, which corresponds to an average weight of such systems.

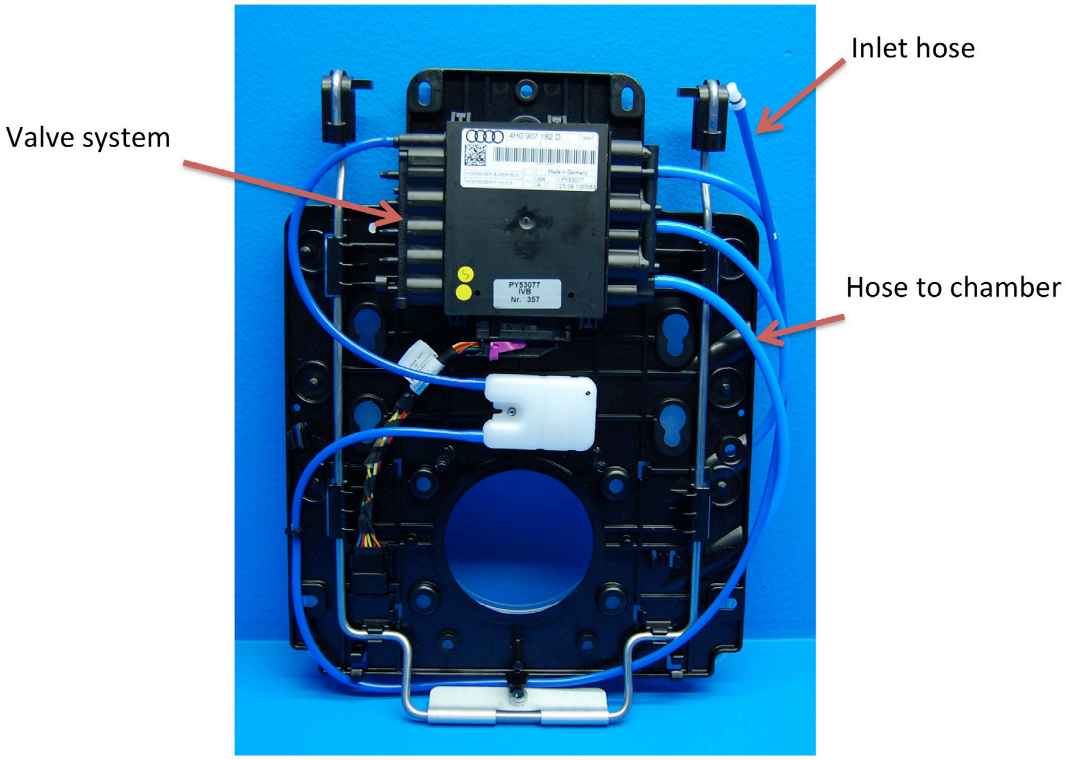

Figure 4.12: Air chamber system, rear view (referring to an internal source of Magna)

The picture in Figure 4.12 shows the relatively complex valve system, the inlet hose and the hoses which feed the chambers.

Motor-actuator system: In principle, such systems always operate with a motor and an actuator. The engine drives the actuator that converts the rotational movement into a translatory motion. This translational movement either leads directly to the deflection of the lumbar adjustment or moves a further mechanism (the deflection tightens a cable that, in turn, presses the adjustment device in the direction of the occupant). At present, Leggett & Platt and Magna use this system for lumbar support adjustment devices.

Figure 4.13 shows a motor-actuator system, again for an Audi A8 (model 2006). This enables an accurate comparison of values.

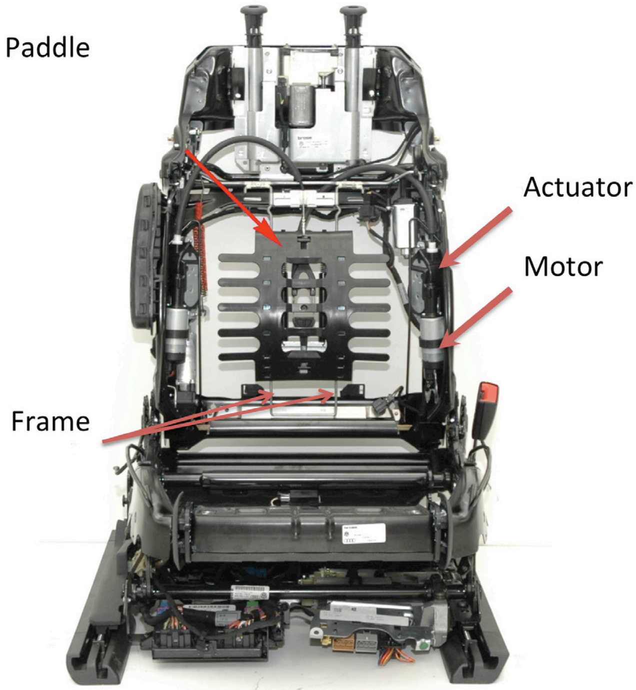

Figure 4.13: Motor-actuator system (referring to an internal source of Magna)

The depth of this system is restricted to 42mm due to the diameter of the motor and the width of the actuator. The weight is 1,1kg for a two-way lumbar adjustment system and 1,74kg for a four-way lumbar adjustment system. The motor and the actuator, with 0,59kg for a two-way lumbar adjustment system, make a significant part of the weight.

Manual system: Manual systems operate the same way as engine-actuator systems do. The motor is replaced by a manual rotation of a knob. Accordingly, the gear ratios are smaller in order to allow the user to set fast. These systems have a very low depth (less than 10mm) and weight is low as well. A direct comparison with MASA is less useful, since a manual system has no actuator or motor. Additionally, the benefit is not the same because the system has no electronic control. Figure 4.14 shows a manual system of a Ford 500 (model 2006).

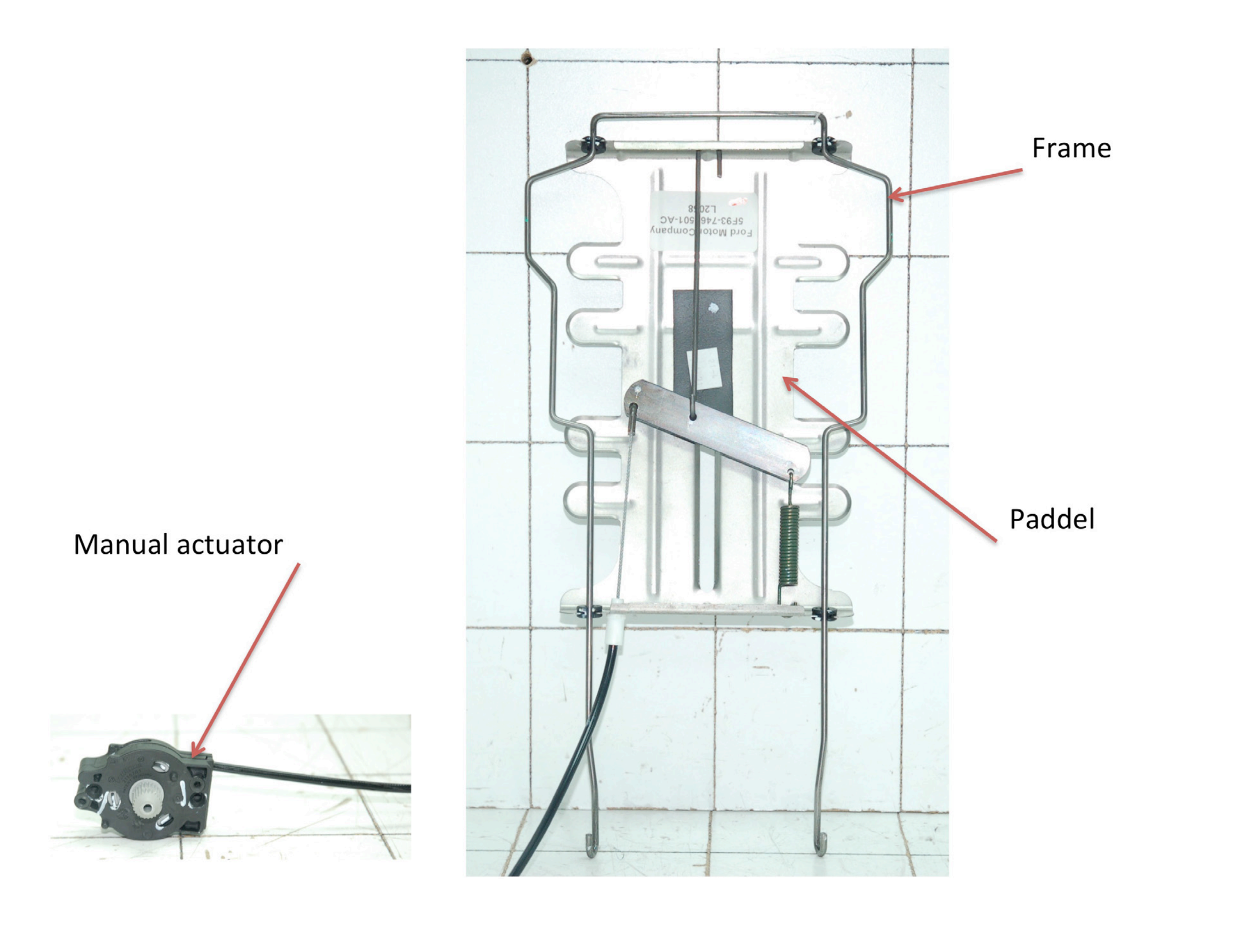

Figure 4.14: Manual system of a Ford 500 model 2006 (referring to an internal source from Magna)

- Comparison of MASA with competing systems

The prototype is designed to be similar to the motor-actuator system as it also has a paddle and accordingly a very similar frame. However, a wire replaces the motor and the actuator. Additionally, two clamps and two springs are needed for wire fixation and reset of contraction. All other parts are the same. Table 4.1 shows the weight calculation for a MASA system, based on the parts of an Audi A8 (model 2006). A weight reduction of up to 35 per cent compared to a motor-actuator system and up to 25% compared to the air bladder system can be achieved.

A weight reduction of less then half a kilo seems to be negligible. However, at present such a weight reduction is of high importance for car producers. This applies to all vehicle classes, since limits on carbon dioxide emmisions will be charged on the entire car fleet. Therefore, it must be tried to reduce at all costs the weight of the vehicle in order to improve the driving characteristics without any increase of carbon dioxide emissions by reference to the acceleration.

Parts Audi A8 model 2006	Part weight / kg		Parts MASA system	Part weight / kg
Actuator	0,3		Wire	0,005
Motor	0,29		2 Clamps	0,02
Paddle	0,262		Paddle	0,262
Frame	0,288		Frame	0,288
			2 Springs	0,15
Total weight	1,11		Total weight	0,725
Weight reduction per seat / kg	0,39			
Weight reduction per seat / %	34,68			

Table 4.1: Weight reduction with MASA system (own illustration)

The valve system on the one hand and the motor on the other hand, restrict the minimum depth of the air chamber system and the motor-actuator system. Since the MASA system does not need these parts, the same width can be achieved as for the manual system. This leads to a significant space reduction.

Competitors

According to a report of Global Insight Automotive the three biggest competitors according to the market share are the seat producers Johnson Controls, Lear and Faurecia. Additionally, Hyunday Dymos could be a strong competitor in future regarding MASA, since the company claims itself as the world´s research leader of car seats and wants to set up facilities in Europe. Figure 4.15 shows the market shares of all car seat producers world wide.

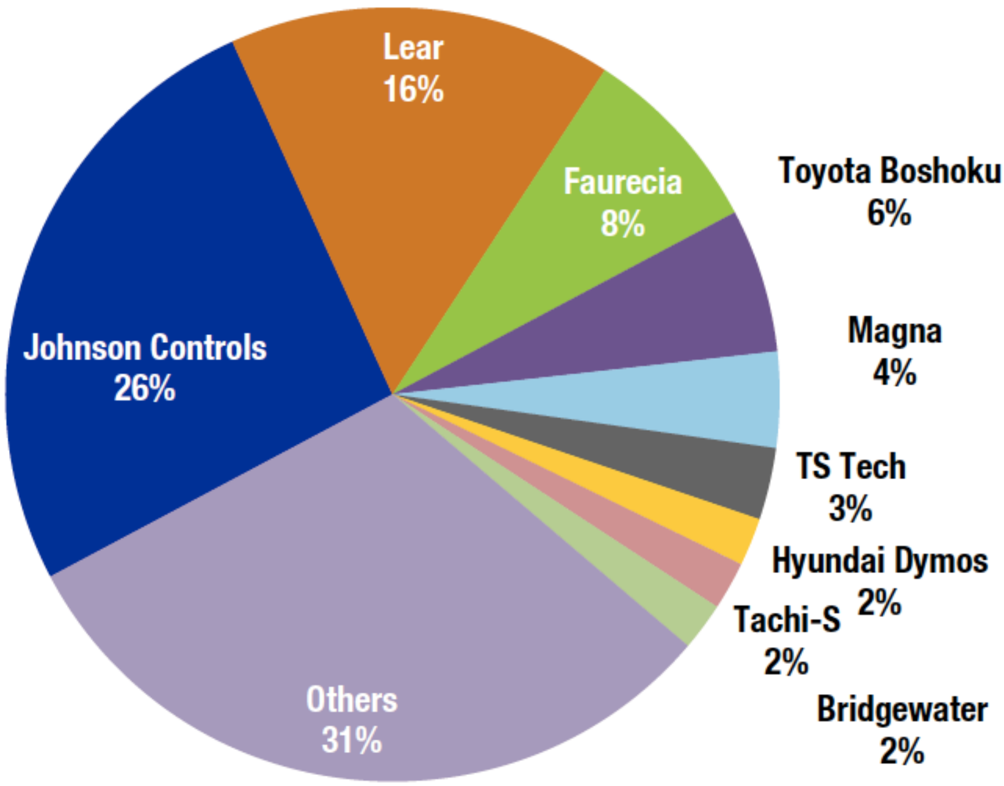

Figure 4.15: Global market share of front seats (Automotive system report of Global Insight, 2013)

Market segmentation and market potential

In consultation with experts from the Market Research & Planning and Corporate Engineering and R&D departments, a market segmentation was performed to identify sales figures for pilot customers and subsequently for all future potential customers. The figures are based on the data provided by Global Insight. Global Insight is a database containing sales forecasts for any car brand worldwide and is also used by Magna. The data is limited to the period from 2013 to 2017, as a consideration of years after 2017 makes no sense due to large, non-estimable influences. In the following discussion, a classification of cars is made. This classification is also used by Global Insight and is illustrated in Table 4.2.

Segment	Example
D	Audi A4, BMW 3er, Mercedes C-class
E	Audi A6, BMW 5er, Mercedes E-class
F	Mercedes SLS, Porsche Carrera GT
HVAN	Mercedes Sprinter, VW Crafter

Table 4.2: Car classification by Global Insight (IHS AutoInsight January 2013)

Market entry

According to experts, the German OEMs such as BMW, Daimler and VW represent the greatest potential for market entry. Since new technologies are always initially installed in luxury vehicles, luxury cars from the above mentioned German OEMs should be considered for entering the market. Another reason for focusing on these OEMs is the existing relationships that help to facilitate an introduction of the new technology.

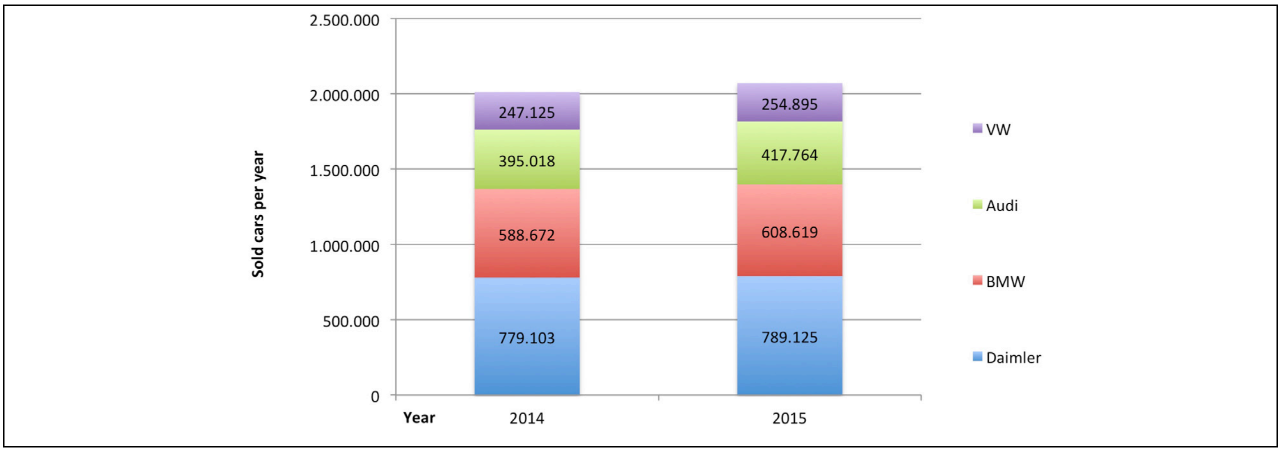

Figure 4.16: Total market potential of the entry market (own illustration)

Figure 4.16 shows the adapted sales figures of the classes E and F of the OEMs Daimler, BMW and VW (Audi separately shown) of 2014 and 2015. Only these two years are illustrated because a market entry before 2014 is not possible and from 2016, the total market potential will be considered for further assumptions (illustrated in Figure 4.16). The diagram shows that, especially Daimler and BMW, sell a high quantity of high-end sedans. It should be noted, however, that VW and Audi are still of strategic importance, since these brands have high sales figures of class D (class D is just considered for the total market potential in order to expand from the total market of the entry market to the total market potential). Compared to the total annual production of cars, the entry market is relatively small. This can be considered to be positive, since a high degree of uncertainty still exists at the time of market development. It is advisable to choose a small market as a pilot market so the risk remains manageable.

In connection with the economic crisis, often a crisis in the automotive market is also spoken. According to an expert at the department of Marketing & Research, the automobile market is currently not in any crisis. He identifies 2008 and 2009 as the real crisis years. Thereafter, sales have continuously increased in all classes and have by far exceeded the values of the pre-crisis year 2007. Only in class E have the values of 2007 not yet been achieved but again, a trend can be detected. Therefore, the market entry via segments E and F represents no risk. Table 4.3 presents the sales figures of segments E and F as well as the sales figures of cars from 2006 to 2013 worldwide. It can be seen that, since 2010, a permanent increase in sales has occurred. The normalised values are very revealing, since they illustrate the development very well.

Global sales segment	2006	2007	2008	2009	2010	2011	2012	2013
E (cars/year)	6.272.413	6.194.397	5.157.792	3.902.351	4.605.732	4.974.591	5.018.137	5.068.564
Change in sales (%)		-1,2%	-16,7%	-24,3%	+ 18,0%	+ 8,0%	+ 0,9%	+ 1,0%
Normalized values related to 2007		100,0%	83,3%	63,0%	74,4%	80,3%	81,0%	81,8%
F (cars/year)	21.433	22.803	19.040	14.178	21.459	23.309	26.068	30.883
Change in sales (%)		6,4%	-16,5%	-25,5%	+ 51,4%	+ 8,6%	+ 11,8%	+ 18,5%
Normalized values related to 2007		100,0%	83,5%	62,2%	94,1%	102,2%	114,3%	135,4%
Total sales:	66.232.771	69.515.052	66.040.129	63.842.155	72.479.079	75.633.806	79.655.935	81.689.030
Change in sales (%)		5,0%	-5,0%	-3,3%	+ 13,5%	+ 4,4%	+ 5,3%	+ 2,6%
Normalized values related to 2007		100,0%	95,0%	91,8%	104,3%	108,8%	114,6%	117,5%

Table 4.3: Total sales of cars and sales of the E and F segments from 2006 to 2012 (own illustration)

- *Market development and full market potential*

After an establishment of the lumbar support adjustment system in the above-mentioned entry market, the next step aims to exploit the full market potential. According to experts, lumbar support adjustment systems already exist in vehicles that are not counted among the upper class segments (Ford Focus, Volkswagen Golf, et c...). The middle class cars therefore definitely represent market potential. Additionally, lumbar support adjustment systems in particular make sense for vehicles, which are driven long distance, or a high annual mileage is covered (examples are company cars like Audi A4, BMW 3 Series, VW Golf and also vans like Mercedes Citan, Mercedes Sprinter, VW Transporter, etc...). It is therefore advisable to convince the German OEMs to also use the MASA technology for these types of vehicles. After the successful implementation of MASA lumbar support adjustment systems in all car types with the potential of the German OEMs, in addition all car types from other manufacturers that meet the above mentioned requirements also represent a high potential. This is especially true for regions where VW, BMW and Daimler have high sales figures, since in these areas a high degree of acceptance for the new technology will already exist. Figure 4.17 shows the full market potential including car classes D, E, F, and HVAN and taking into account the above-mentioned criteria.

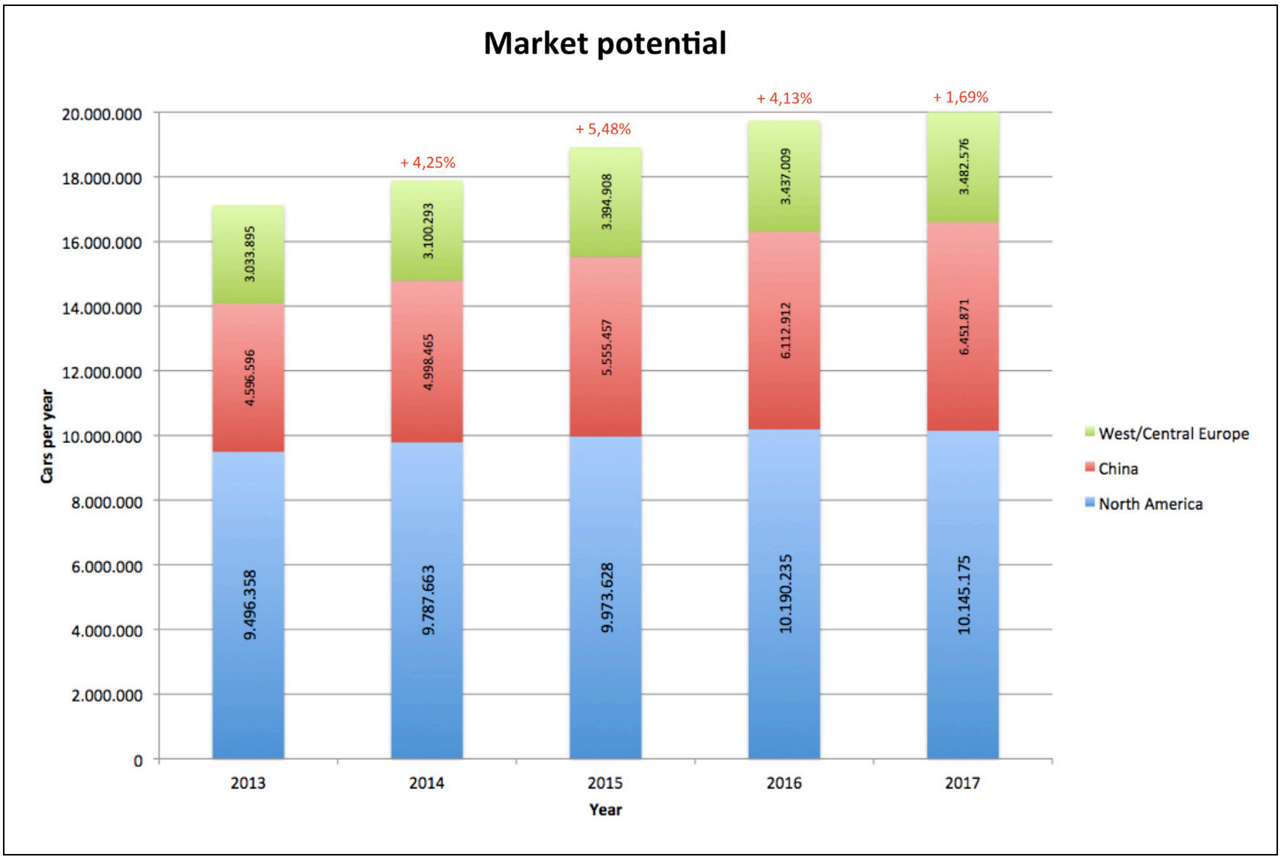

Figure 4.17: Total market potential of MASA for a lumbar support adjustment system (own illustration)

Regionally interesting and relevant markets are North America, Western and Central Europe and China (including India). It is striking that depending on the region, different brands are interesting for a market enlargement. These are, for example, in North America; Ford, Dodge, Chevrolet, and GMC, in China; Buick and Great Wall and in Europe; Opel (Insignia, Vivaro), Peugeot (508, Expert) and Volvo (XC 60). It is worth mentioning the development of the VW Passat in China, since, in the coming years, an extreme increase in sales can be expected. From 2013 to 2017, the predicted numbers double to approximately 500.000 units. In principle, the development of the market in China is interesting because a greater increase of the market potential can be recorded compared to other markets. In particular, a high increase in sales of the classes E and F can be expected.

The Japanese market is excluded in the medium-term market potential, since domestic brands dominate there. The German OEMs in this region sell significantly less cars. If the situation changes for the better in the long run (there are significant increases in sales of non-Japanese cars) as well the Japanese market can be taken into consideration.

In summary, as a final market potential, the complete upper class segment can be considered. Additionally, all middle-class vehicles and vans, which are usually high mileage driven, represent market potential. Promising regional markets are North America, Western and Central Europe and China. However, a full exploitation of the market potential is unrealistic due to the strong competition with other car seat producers. Referred to Global Insight, 81,5 million cars were produced in 2012 and Magna equipped 5%of these cars with front seats. Subsequently 30% of these seats were equipped with a lumbar support adjustment system, which corresponds to 1,2 million cars in 2012. Table 4.4 shows the total market potential and the expected market share of Magna from 2014 to 2017. The expected market share for the competitors cannot be pictured separately, since such an analysis involves too high costs at this stage.

	2014	2015	2016	2017
Total market potential[7]	35.772.842#	37.847.986#	39.480.312#	40.159.244#
Expected market share for Magna	401.000#	1.606.000#	5.150.000#	14.860.000#

Table 4.4: Expected market share of Magna compared to the total market potential (own illustration)

4.2.4 Benefit Analysis

The benefit analysis is a method for decision support in the selection of complex alternatives (Gelbmann et al. 2003, p. 74) with the intention of sorting the alternatives with consideration of the preferences of the decision maker (Zangemeister 1976, p. 45).

The benefit analysis consists of five steps. In the initial step, the criteria are weighted because not each of them has the same importance. The pairwise comparison is proven as an assessment procedure for weighting. Weighting is followed by the evaluation. It is advisable to represent the relationship between achievement of goals and goals with the help of an evaluation scheme. After the evaluation, the partial benefit values are obtained by multiplying the weight with the value that represents the achievement of goals of each criterion. The total benefit value is then obtained by summing up the partial benefit values. Finally, a sensitivity analysis determines the stability of the result by showing in which way the result of benefit analysis changes when varying the weighting. If even a strong variation does not change the ranking, experts speak of a stable hierarchy (Gelbmann et al. 2003, p. 75).

[7] The total market potential and the market share in numbers of sold front seats, which are equipped with a lumbar support adjustment system per year.

Since the comparison of MASA and similar systems is only enforceable with a method that can take into account both, quantitative and qualitative criteria, a benefit analysis seems to be adequate. It aims to assess whether or not the new technology is more beneficial than the one currently used. As an initial step, a description of the problems that can arise for the end user when using a lumbar support adjustment system should facilitate determination of the target criteria. The second step is then trying to identify target criteria on the basis of the problem definition, the SWOT and the functional analysis, which can have a technical, economic and environmental origin. It was deliberately ensured that only six to seven relevant criteria are used to make the evaluation less complex. The analysis focus again on a lumbar support adjustment system but also includes criteria related to general use. The restriction is only made in order to increase the validity of the quantitative criteria to ensure the high accuracy of the analysis. The project team evaluated the criteria as a final step.

Problem definition

Not only a detailed description of the product is crucial (description in chapter 4.1.1) but also a description of the problems that occur during usage is of importance, since the problems are directly related to the benefits.

The main problems that currently occur or could arise with respect to the new system are:

- *Lack of space*: A lack of space, caused by the installation of numerous comfort applications, directly decreases the comfort of the user.
- *Noise generation*: The technologies used currently generate noise that reduces user comfort.
- *High weight*: A reduction of weight reduces the fuel consumption. Even a small weight reduction is of importance for OEMs and car manufacturers in order to stay competitive. The reason is, that the government reduces the CO_2 emission limits continuously. At the same time new cars should be improved regarding the acceleration and the fuel consumption. This is true for all car classes due to the fact that the CO_2 emission are averaged over the entire fleet.
- *Technical failure*: A high number of complex comfort applications increase the probability of failure.
- *Functioning of the Control system:* The control method of the adjustment system can influence the comfort of the user. The control system can be either incremental or continuously variable. Additionally, the control speed influences the comfort of the user.
- Resistance against environmental effects: The environment and especially the temperature and humidity, can affect the functionality of the system.

- Low lifetime: The adjustment system has to work properly during the entire lifetime of the car.

Identification of Criteria

As already mentioned above, the criteria were identified based on the problem definition, the SWOT analysis and the function analysis. The derived criteria are illustrated in Table 4.6, which were weighted using a priority matrix. The resulting relative decimal values represent the relative importance of each criterion. It must be mentioned that the determination of benefit criteria was difficult because Magna Seating has no relevant information on end-users. However, the project team tried to assign two values to each criterion, corresponding a very bad and a very good performance level. For example, the size criterion shows a high degree of performance if the depth is less than 10mm and a very poor performance if the width is more than 30mm. Thus, it is easier to evaluate the criteria objectively. These performance values are presented in Table 4.5.

Criterion	Outstanding performance	Poor performance
Low space consumption (width of the system)	10mm	30mm
Low weight	0,5kg	2kg
Regulating speed	5cm/s	0,5cm/s
Maximum adjustment range	5cm	1cm

Table 4.5: Performance values of the criteria (own illustration)

Description of the criteria

Functional reliability: The criteria “low life time”, “resistance against environmental effects” and “technical failure” are summed up to the criteria “functional stability”.

Low space consumption: Lumbar support adjustment systems move vertical and horizontal. Thus, the width and the height of the system cannot be reduced. However, the depth is of high importance because it restricts the depth of the seat.

Low weight: The low weight contributes to savings in CO_2 emissions. Even a low reduction of weight is of importance in this regard.

Regulating speed: The regulating speed defines the velocity of the adjustment. The driver perceives a too low speed as irritating.

Maximum adjustment range: The maximum adjustment range defines the distance between the maximum and minimum deflection. A too small adjustment range causes dissatisfaction of the occupant.

...is more important as...	Functional reliability	Low noise level	Low space consumption	Low weight	Regulating speed	Maximum adjustment range	Vertical sum	Relative decimal value
Functional reliability		5	5	5	1	1	17	0,21
Low noise level	0,2		5	10	5	5	25,2	0,31
Low space consumption	0,2	0,2		10	0,2	5	15,6	0,19
Low weight	0,2	0,1	0,1		0,2	5	5,6	0,07
Regulating speed	1	0,2	5	5		5	16,2	0,20
Maximum adjustment range	1	1	0,2	0,1	0,2		2,5	0,03
						Sum	82,1	1,00

1 = equal
0,1 = much less important
0,2 = less important
5 = more important
10 = much more impotant

Table 4.6: Weighted criteria and relative decimal values (own illustration)

Evaluation of criteria

In step three, the criteria were rated with a value of one to ten, relating to their performance level[8]. Experts from various disciplines carried out the analysis to exclude subjectivity. Table 4.7 shows the rating table with the resulting average benefit values.

	Weighting	MASA system		Motor-actuator system		Air bladder system	
		Evaluation	Benefit value	Evaluation	Benefit value	Evaluation	Benefit value
	g	x	x•g	y	y•g	y	y•g
Functional reliability	33%	7,5	2,48	7,5	2,48	7	2,31
Low noise level	17%	10	1,70	3	0,51	5	0,85
Low space consumption	19%	8,5	1,57	4,5	0,83	6	1,11
Low weight	13%	8	1,00	4	0,50	5	0,63
Regulating speed	15%	8,5	1,28	7,5	1,13	7,5	1,13
Maximum adjustment range	4%	3	0,12	7,5	0,30	8	0,32
	100%		8,14		5,74		6,34

Table 4.7: Rating table with averaged benefits values (own illustration)

[8] One means that the product does not meet the criterion at all, whereas ten means that the product meets the criterion in the best possible way.

Table 4.7 shows that the MASA technology has a higher benefit value compared to the motor-actuator system and the air bladder system. Therefore, a higher target price could be considered for the new product.

4.2.5 Cost Evaluation

At present, Magna does not produce lumbar support adjustment systems in-house but buys them from suppliers. Therefore, the most conceivable situation is a licence sale of the new technology, since Magna Seating does not show interest in building up a production. However, experts do not entirely exclude the possibility of starting a production of such systems in future.

All following considerations are based on the assumption that Magna will exploit the idea by licence sales. The cost evaluation therefore includes the development costs and patent costs but no costs for the installation and development of production systems or any other costs that are related to a ramp up of an in-house production.

Development Costs of the lumbar support adjustment system

The development costs for a lumbar support adjustment system are made up of expenses for the project management, the computer aided design, development of the control system, prototype tests, prototype parts and pre-serial tests. The prototype testing includes tests for durability, heat dissipation and functional stability. The pre-serial tests aim to examine the functional stability in detail and include environmental aspects (climate test, fatigue test, heating-cooling test, tropic test, temperature change test, heat exchange test, pulsator test, and endurance test). The total costs were estimated by an expert and amount to approximately 200.000 euros. Figure 4.18 shows an overview of the cost situation related to the development. Safety tests were not assessed because they differ from country to country and are usually the task of the supplier. Thus, the company that produces and sells the product has to carry out such safety testing.

Development costs of a lumbar support adjustment system using the MASA technology

			Costs
Project management			€ 25.000
CAD design costs			€ 20.000
Electronic-control tests			€ 50.000
Prototype parts			€ 25.000
Prototype tests	Durability tests		€ 30.000
	Heat dissipation tests		
	Functional stability	- Pulsator test - Endurance test	
Pre-serial tests	Environment tests	- Climate test - Fatigue test - Heating-cooling test - Tropic test - Temperature change test - Heat exchange test	€ 50.000
	Functional stability	- Pulsator test - Endurance test	
		Total costs	€ 200.000

Figure 4.18: Development cots of a lumbar support adjustment system using the MASA technology (own illustration)

Patent costs of the lumbar support adjustment system

Together with experts of the patent department of Magna, the costs for a patent of the new technology have been evaluated. In the case of the market strategy, it makes sense to file a patent for Europe (European Patent) initially and expand it at a later moment for China and North America. The composed costs for such a patent strategy are shown in Figure 4.19.

Patent costs per year and region

<table>
<tr><th>Year</th><th>Europe</th><th>China</th><th>US, Canada</th></tr>
<tr><td>2013</td><td rowspan="3">€ 4.000</td><td rowspan="4">€ 5.000</td><td rowspan="4">€ 10.000</td></tr>
<tr><td>2014</td></tr>
<tr><td>2015</td></tr>
<tr><td>2016</td><td>€ 7.000</td></tr>
<tr><td>2017</td><td>€ 700</td><td>€ 2.500</td><td>€ 2.600</td></tr>
<tr><td>2018</td><td>€ 700</td><td>€ 2.500</td><td>€ 2.600</td></tr>
<tr><td>2019</td><td>€ 700</td><td>€ 2.500</td><td>€ 2.600</td></tr>
<tr><td>Total</td><td>€ 13.100</td><td>€ 12.500</td><td>€ 17.800</td></tr>
<tr><td></td><td></td><td>Total costs:</td><td>€ 43.400</td></tr>
</table>

= cumulated costs from 2013 until 2016 (costs until granting of the patent)

= cumulated costs from 2013 until 2015 (costs until granting of the patent)

Figure 4.19: Patent costs for MASA (own illustration)

4.2.6 Market lifecycle calculation

The aim of the market lifecycle calculation is the assessment of possible profits or losses in the future. This is to minimise the risk for the decision makers. The assumptions are based on scenarios that simulate either a more or a less favourable development. Therefore, the first part of the market lifecycle calculation deals with the development of scenarios, taking into account the theory for scenario modelling and information from experts of Magna. The second part aims to compare all costs and income that are related with the respective scenario on a chart. As of yet, no lumbar support system was produced in-house (and it can also be assumed that Magna does not go into production) a license sale is considered in order to exploit the idea.

Scenarios

The scenario technique aims to describe the future development of a present situation, depending on different framework constellations. In this way, not only one but several futures are conceivable. The scenario technique therefore seeks to demonstrate a wide range of future possibilities that may be involved in the decision-making process. In literature, the scenario technique is often explained with the so-called scenario funnel shown in Figure 4.20 (Koch 2004, p. 302; Seibert 1998, p. 209).

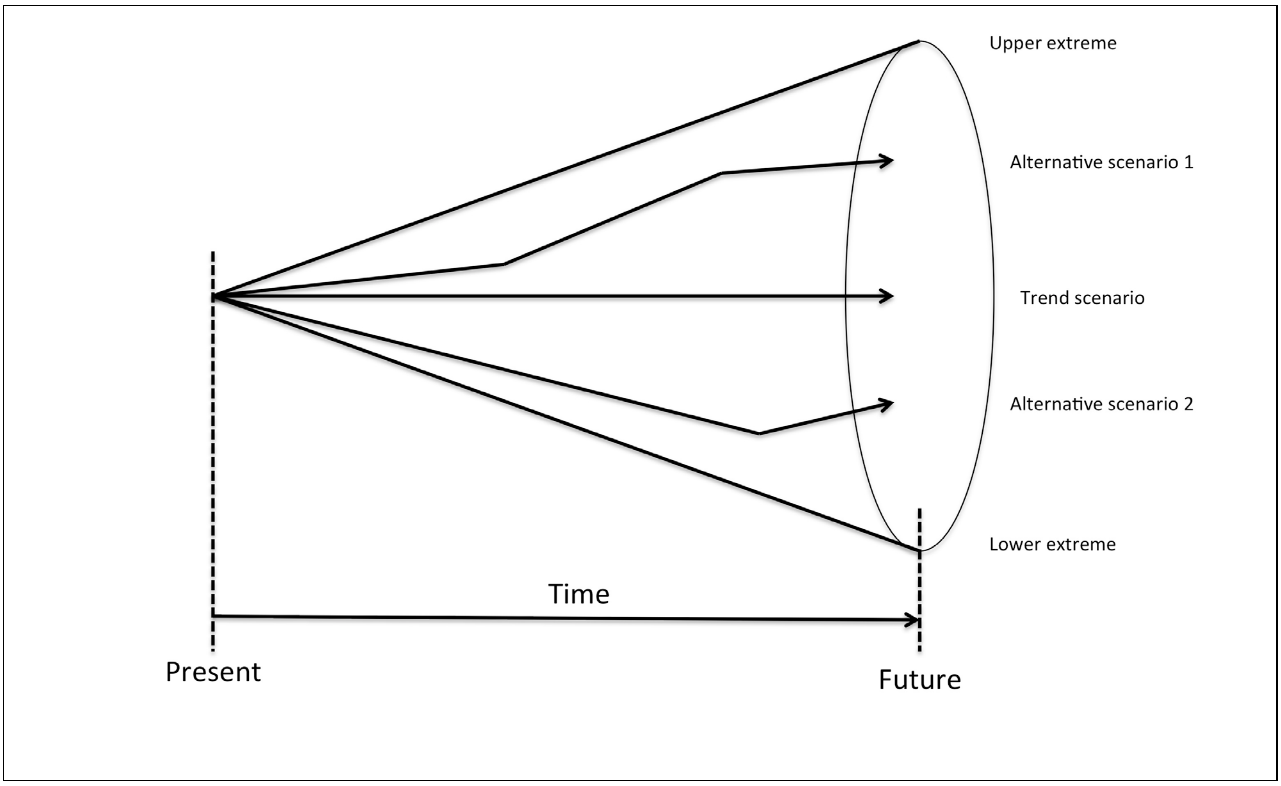

Figure 4.20: Scenario funnel (Seibert 1998, p. 210)

The funnel expresses that the number of alternatives increases sharply with greater distance from the present. The funnel edges represent extreme situations. All other possible scenarios lie within the funnel. In practice, usually three to five variants are developed, with at least two extreme variants and a trend scenario (Koch 2004, p. 303).

The key elements of the method are made up of the entry of the main environmental factors, the determination of alternative projections for these factors, and their subsequent combination to a coherent overall picture (Seibert 1998, p. 210).

Scenario analysis requires a structured approach and is therefore divided into several steps. The problem-analysis defines the object of study. The subsequent environmental analysis serves for the collection of factors that influence significantly the future development of the research object. These factors are described in terms of their future trends and compared in a cross-impact analysis to identify possible interactions. Following this, the scenarios can be formulated and interpreted based on the previous findings. In a final step, the respective consequences of the scenarios on the object of study are described. The development of scenarios is very time consuming and is carried out by a cross-functional expert team (Seibert 1998, p. 210).

Problem analysis (formulation of the subject of investigation)

The object of the scenario analysis is the formulation of future sales, scenario depending costs and the estimation of target levels for the license fees of the new product, to subsequently determine future profits and losses.

Environment analysis

The environmental analysis identifies the factors that influence the subject of investigation. In the case of a lumbar support system, using the MASA technology, these are the level of acceptance of the OEMs and end-users, the technological implementation of the idea, the development costs, possible competitors, the global economic situation and the price of the product.

Future assumptions

The future assumptions are not arbitrary but are based on all information that was available at this time.

Acceptance level of the OEMs and end-users: The level of acceptance is highly dependent on benefits. In principle, it is easy to enter markets with products that have significant advantages. In the future, no change of this trend is expected. A high product price influences the acceptance in a negative way.

Technological implementation of the product idea: This factor can be regarded as critical. If the current doubts in respect to the technological feasibility of the product are eliminated, this factor should not adversely affect the sales figures. If, however, problems occur that cannot be overcome, this would lead to the worst case that the product idea could not be exploited economically.

Competitive products: This factor can be regarded as critical. If a competitor is able to bring a product that meets the needs of customers in the same way or better onto the market, it would affect the sales dramatically. If the competitors are not capable of launching a similar product on the future market, however, a very large share of the available market potential can be used.

The global economic situation: The global economic situation related to the automotive market is stable. Sales figures show that currently, all vehicle classes are on the rise and no medium-term changes are in sight.

Development and patent costs: In the case of exploitation of the idea in the form of license sale, the development and patent costs are the only costs created. These costs are dependent on the technical implementation. Problems with the development automatically lead to higher development costs. The patent costs, however, can be expected to be stable.

Scenario writing

Scenario A (optimistic case): The acceptance of the OEMs and end-users is due to the innovative approach and the fulfilment of all customer needs is extremely good (80% of the targeted customers apply the technology for their products). The technical implementation proceeds according to the plan. There are no delays during the entire development phase and therefore no unforeseen development costs arise. The competitors cannot exert significant pressure with comparable or better products, thus the market potential can be exploited. The global economic situation behaves as expected and sales forecasts for the automotive markets occur with little deviation.

Scenario B (trend): The acceptance of the OEMs and end-users is due to the innovative approach and the fulfilment of all customer needs is relatively good (40% of the targeted customers apply the technology for their products). The technical implementation proceeds according to plan. Even possible problems can be solved with alternative approaches (a similar control system has already been used in servos; alternatively, Smarter Alloys confirmed that an incremental control system is possible). However, this could well lead to a delay of the planned launching date of the series product and cause unforeseen development costs. Additionally, a competitor exerts significant pressure with another product, which has a negative influence on exploitation of the market potential. The global economic situation behaves as expected and sales forecasts for the automotive markets occur with little deviation.

Scenario C (worst case scenario): The acceptance of the OEMs is not as large as originally anticipated and technical problems arise that can be solved only by means of extensive time and manpower. The situation causes a considerable delay in developing the product. The competitors have already brought a comparable product onto the market and therefore the OEMs cannot be convinced to implement the lumbar support system with MASA technology in their cars.

Impact analysis

The impact analysis shows the impact on the subject matter regarding the respective scenario and the criteria.

Scenario A (optimistic case): The potential of the entry market can be exploited perfectly due to the fast progression of the project and the high acceptance of the OEMs and end-users. All mentioned OEMs show interest in the technology and implement it in most vehicles of classes E and F in 2014 and 2015. After the successful launch almost all the other above mentioned potential customers show interest so that, by 2015, 80% of the entry market and in 2017 80% of the total market potential is exploited. The development costs are, as estimated, 200.000 Euros. Also, the patent fees are as expected, at about 43.000 Euros. The license fee of the product can be set with 1.5%of the product price. For each car, two lumbar support adjustment systems are integrated, one for the driver and one for the passenger seat in the front. The average product price of state of the art systems is about 12 Euros. The income per car eat would be 18 Cents.

Scenario B (trend scenario): The potential of the entry market can be exploited due to the fast progression of the project and the high acceptance of the OEMs and end-users. However, little delays due to problems with the technological implementation lead to higher development costs (250.000 Euros). Since the competitors exert pressure, not all named OEMs can be convinced to use the new product for their cars so that, by 2015, 40% of the entry market and by 2017, 40% of the total market potential is exploited. The license fees are set with 1% of the product price, which corresponds to an average level of license fees in this field. The income per seat would be 12 Cents.

Scenario C (worst case scenario): The market potential of the entry market cannot be exploited at all due to the insufficient technical implementation and the low acceptance level of the OEMs and end-users, even after higher investments than planned. The development costs are, at 300.000 Euros, much higher than expected. The technological problems can only be solved by means of high investments. Additionally, a competitor already launched a similar product, so the management decides to suspend the project and the idea cannot be exploited.

	Best case scenario	**Trend scenario**	**Worst case scenario**
Development costs	200.000€	250.000€	300.000€
Patent costs	43.400€	43.400€	43.400€
Patent fees per system	18 Cents	12 Cents	8 Cents

Table 4.8: Costs and income of each scenario (own illustration)

Table 4.8 shows a comparison of all costs and incomes regarding a license sale and the respective scenarios. Subsequently, Figure 4.21 compares the scenario dependent future development of the profit and losses.

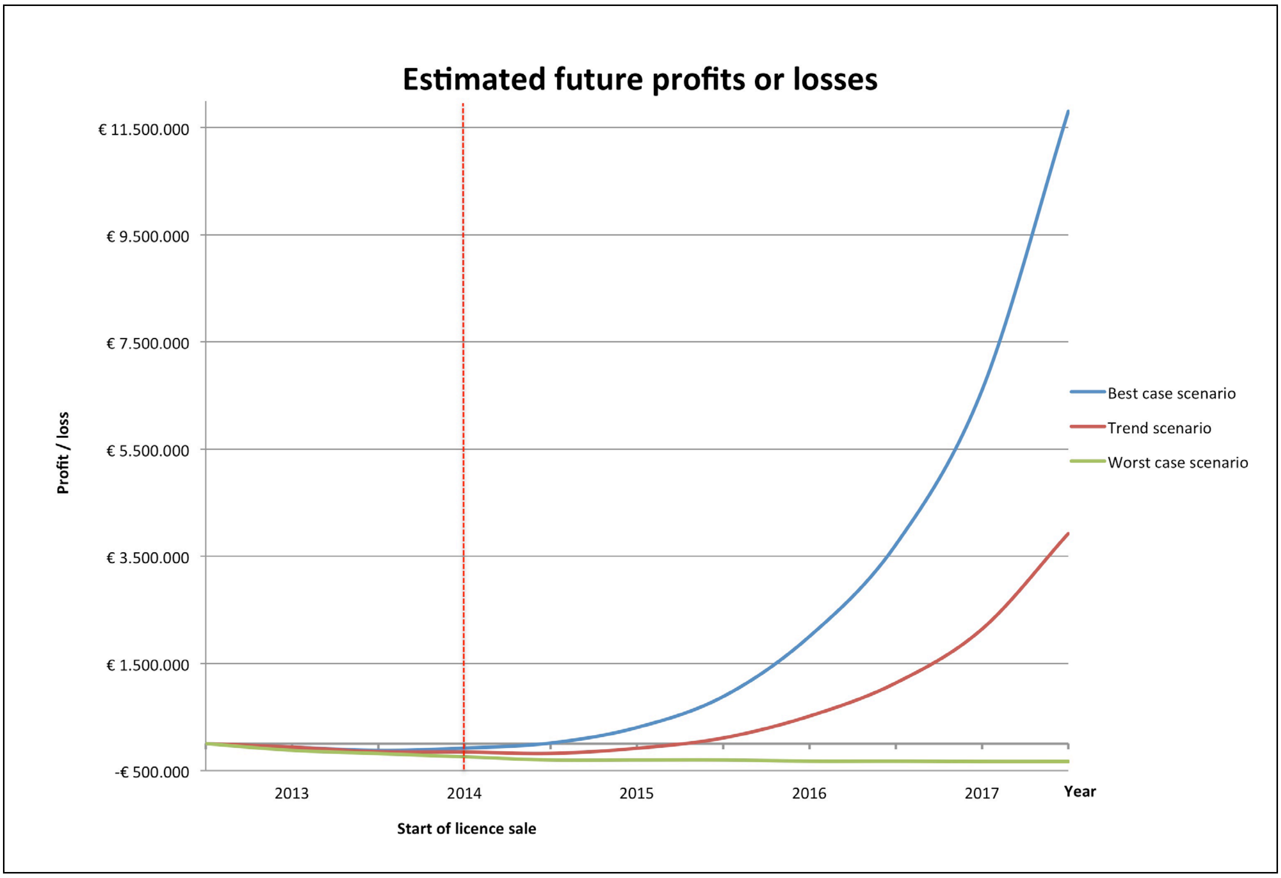

Figure 4.21: Estimated future profits or losses (own illustration)

4.2.7 Legal requirements

It is important to clarify at an early stage of the innovation process, whether or not the product has to fulfil any legal requirements in order to avoid redesign due to legal misconduct. Together with an expert from Magna Steyr, it was found that a lumbar adjustment system in general does not need to be subject of an authorisation procedure. However, an obvious risk for occupants cannot be present.

Since the lumbar support adjustment system includes electronic components, it must be tested according to ISO (International Organization for Standardization) 26262. ISO 26262 is an international standard for the verification of the functional safety of electronic components for road vehicles with a weight not exceeding 3.5 tonnes (Hillenbrand 2011, p.92).

During the process of proving functional security, three ratios are used to classify failures. These ratios are exposure (E), control (C) and severity (S). E stands for the frequency, C for the controllability and S for the effect of a failure occurring. Together, these three indicators build the Automotive Safety Integrity Level (ASIL). The higher the ASIL, the stricter the security requirements (Hillenbrand 2001, p.95).

The ASIL has to be evaluated separately for each failure that could possibly occur. Together with an expert from Magna Steyr, the following possible failures could be identified:

Accidental deflection of the system

The system no longer responds to the user and performs arbitrary displacement. This failure does not present any hazard to the end-user. No action has to be taken.

The wire heats up without control

The wire is heated up by the means of electric power. If the heating is out of control, the wire could reach very high temperatures and cause a fire. The expert rated this failure as ASIL A-B (E4: can happen any time, S1-2: small to possibly fatal injury if the wire causes a fast progressing fire, C1-2: easily manageable - lean forward, pull the car over, freeing other car occupants). ASIL A-B represents a low security level and can be secured with the normal functional security process regarding ISO 26262. In order to avoid any problem during this functional security process, it is important to take action. The expert suggests using an incombustible material to insulate the wire.

The electronic control system causes fire

The same applies here as to a wire without control. No problems should occur during the functional security process if sufficient insulation is kept in mind.

4.2.8 Patent research and application

The patent research is used to identify ways of protecting the innovative product in order to discourage imitation and to enable a license sale. By the end of the project, no patent application had yet been commissioned. The research has shown, however, that in the area of seat adjustment systems, some patent applications that use SMA have already been filed. Therefore, an early realisation of a patent application would be beneficial.

4.2.9 Prototype testing

The SWOT analysis has pointed out that the heat generation could cause problems. Furthermore, it has to be ensured that the system does not consume more power than a car battery can provide. To rule out such problems, tests were performed on the prototype.

A SMA wire with a diameter of 0.3 mm was used and continuously heated up to 60° Celsius. Even after 20 seconds, no noticeable differences in temperature on the seating surface could be detected. Figure 4.22 shows that the test setup differs greatly from a real situation, since heat can be transported easily by air movement. This is not possible in a real car seat. It is therefore necessary to perform further tests using an advanced prototype, which is installed in a real car seat. In case there are problems with heat dissipation, it would be possible to replace the design with permanent warming by a version with fixation mechanism. In this case, a power supply of only 0.5 seconds is sufficient to contract the wire. After that, no more energy is required to keep the wire in position.

Figure 4.22: Test design of prototype one (referring to an internal source of Magna)

A voltage of 4 volts and a current of 2 amperes was required to generate the deflection. This gives the equivalent of a power of 8 watts and represents only a small fracture of the power that a state of the art car battery supplies (GS-batteries Website, 27.5.2013). Additionally, the alternative version with a locking mechanism needs power for a very short time and therefore represents no particular strain for the electrical system.

4.2.10 Additional application possibilities and areas

The MASA technology could replace a large number of adjustment systems used currently. As an initial step, the technology can be used for further adjustment systems in the seat area. Figure 4.23 denotes a seat and possible functions, which could be implemented using MASA.

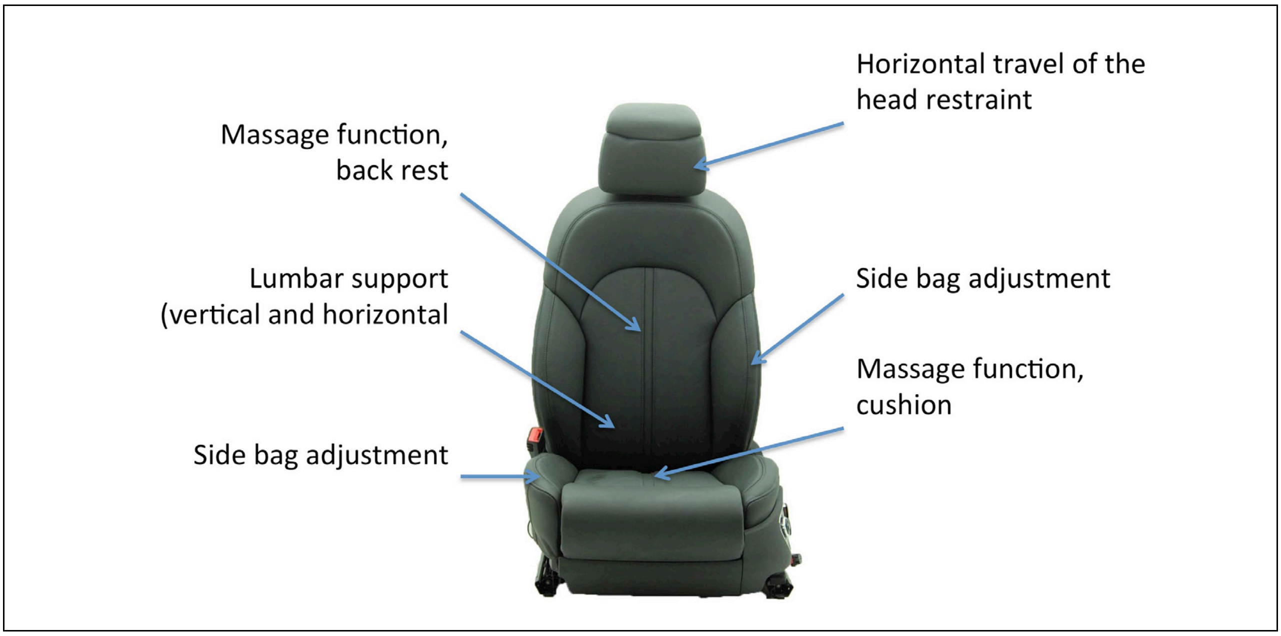

Figure 4.23: Application possibilities of MASA for a car seat (own illustration)

As a second step, the technology can be applied in other areas of the car. In principle, functions, which require a movement that currently performs a traditional actuator are conceivable but especially those functions are suitable for the utilisation of the technology where the displacement is small. Table 4.9 shows possible functions that could be realised with MASA in future.

• Window lift system	• Adjustment system of the rear lift gate
• Locking mechanism for the fuel inlet	• Windshield wipers control system
• Locking mechanism for car doors	• Pedal height control
• Sliding roof mechanism	• Steering wheel adjustment system
• Ventilation flap adjustment system	• Rear view mirror adjustment system
• Mirror control system	• Trunk locking mechanism
• Adjustment system for bending lights	

Table 4.9: Application possibilities of MASA in a car (A2Mac1 data base, March 2013)

As a third step, the use of the technology for non-automotive applications is conceivable. In this context, the application of the technology for office seats with adjustment functions or massage seats would be conceivable. MASA car closing mechanisms can also be used for other closing applications. In principle, an application by MASA can always be considered if space, noise and weight are important criteria.

4.2.11 Cooperation potential

In order to develop a product for serial production, cooperation with an SMA supplier is necessary. This chapter provides an overview of possible cooperation partners in order to develop the new technology.

SEAS Group

The SEAS Group produces Nitinol wires, tubes, sheets and stripes for the automotive, medical, aerospace and defence market. The company sees itself as the global leader of innovation and production in the field of Nitinol alloys and other super-elastics. Embedded in the SEAS Group, the Actuator Solutions GmbH is able to develop actuators and solutions based on SMA. The company already has experience in developing actuators for the automotive industry and provides Nitinol melting and materials, a complete range of Nitinol fabrication and finishing as well as support in both prototyping and production. The SEAS Group fabrication and finishing processes include complex shape-setting and heat treatment, laser cutting, custom grinding, joining and welding, coiling, surface finishing, coatings and plating. With these competences, the SEAS Group is able to deliver any final or semi-finished component a customer can conceive. The company seems to be a promising candidate for cooperation, due to the location of Actuator Solutions in Germany, the willingness to cooperate and the existing expertise on the field of actuators for the automotive market (Memry Website, 19.2.2013; Company Expert).

Smarter Alloys

The company around Dr. Khan made the breakthrough discovery that applying a high power density energy source to a Shape Memory Alloy (SMA) could produce local transformation in the microstructure. At present, single parts are only capable of performing a single function. With the ability to create local differences in microstructure, single parts are capable of performing multiple functions. An easy embedding of multiple memories in a standard memory metal that responds over a range of different temperatures is enabled by this technology. It could be used for automotive applications with incremental adjustment devices that do not need a sophisticated controlling system (Smarter-alloys Website, 20.2.2013).

The company ensures that the material withstands a cycle number of between hundred of thousands and a million, when used properly. Smarter Alloys applies their Multi-Memory-Material technology to commercially available SMA that are readily available for automotive applications. An expert from the company stated that the price, depending on the complexity and the mass of the product, is typically only a fraction of alternate systems (for example replacing an electromagnetic actuator). The new technology of Smarter Alloys makes an incremental control of adjustment devices possible. The expert from the company suggests embedding several different memories and each of the memories requires a different amount of current for activation. Hence, several adjusting steps will be achieved. The environmental temperature influence can easily be avoided by choosing an operating temperature that is higher than the environment temperature. This approach represents a promising alternative to the continuous control system.

Nimesis Technology

Nimesis Technology is a French company with further locations in Luxembourg, Belgium and Germany. The company produces a wide range of materials, including Nitinol, Nickel-Titanium-Copper and Nickel-Titanium-Iron. Next to Nitinol, Nickel-Titanium-Copper could especially be used for adjustment devices because it is cheaper than Nitinol and has similar characteristics. The company ensures a mass production of the customised product after a validation of prototypes. A Nitinol wire with a diameter of 0.38mm and a start temperature of 83 degrees costs 1,52 Euros per meter, not considering price reduction due to mass orders. Nimesis Technology has production resources to manufacture small, medium or large series, whether it is springs, wires, components in strip shape, or more massive devices. The company develops prototypes according to customer expectations, keeping in mind the future production to ensure a high productivity of series production (Nimesis Website, 20.2.2013).

As well as this three manufacturers of SMA wires Dynalloy, Admedes, Smarter Wires and Norman Noble can be named.

4.2.12 Aggregation

The business plan is a tool for displaying relevant aspects with respect to future decisions of the project's progress and is derived from the previous analysis. It serves in particular, for all those who are not yet familiar with the topic. A business plan concept serves as a template, which was already used for similar projects and has been proven. This ensures completeness of content. The concept envisages a subdivision into five chapters:

- Business concept
- Market
- Competition
- Risks
- Revenue potential and financing

Chapter one explains the concept of the idea in detail, shows the application possibilities and indicates the benefit increase in order to give the reader a basic idea of the innovation. Chapter two deals with the potential. It also refers to the customer profile and recommends a market strategy. Subsequently, competition with other technologies and companies will be discussed. Chapter three also points to potential synergies. Chapter four deals with the possible risk arising in connection with the realisation of the product idea and includes proposals for measures to counteract these risks. Finally, the revenue potential and financing are discussed. The entire business plan can be examined in Appendix B.

4.3 Idea Realisation

The third phase of the innovation process deals with the concrete realisation of the idea, the sale of the product on a proper market and the control of the acceptance of the users. Whether the idea will be realised or not depends to a large extent on the decision of the department of Corporate Engineering and R&D, as well as participating partners who are interested in using the idea for their product range. As previously mentioned, the application potential of the idea is large. However, a realisation seems most likely in cooperation with Magna Seating.

The corner stone for a concrete realisation of the idea in the form of a lumbar support adjustment system was set with the first prototype. If there will be an actual realisation of the idea in the future, more testing has to be made and prototypes have to be constructed in order to reach the production stage. The creation of a specification sheet is advisable and it should include the internal and external customer requirements as well as all the relevant features of the technology concept.

5 Conclusion

This chapter includes a summary of the theoretical part and the practical part. Recommendations for the future course of the project conclude this diploma thesis.

5.1 Summary

The aim of this thesis is the evaluation in terms of technical and economic feasibility of an innovative idea with the name MASA. The idea resulted from the Win Initiative, which is a platform that has been called into life by Magna International and intends to increase the innovative activity within the firm. The present feasibility study aims to support the management decision regarding a realisation of this idea.

The theoretical part contains a clear delineation of concepts and distinguishes different types of innovation and their characteristics. Subsequently, it deals with Innovation Management and the incorporation of Innovation Strategy and Innovation Management into the entire company.

The time span of an innovation process can be divided into different phases and includes activities that are necessary to move from an idea to its practical implementation. To make the whole system manageable, a large variety of approaches regarding the subdivision of the innovation process in phases, steps or stages can be found in literature. The theoretical part explains the most important models.

As well as the background on innovation, it is important to provide the reader with information regarding SMA, which is the core element of this innovative product. Nitinol, a nickel titanium alloy, has especially promising material properties that allow the realisation of targeted longitudinal movement and torsion. Thus, it enables the substitution of traditional adjustment systems.

The practical part mostly focuses on increasing the acceptance of MASA within Magna but also for OEMs and end users. It was necessary to use analytical tools that are appropriate for each step of the innovation process. The significant advantage of MASA is the simultaneous reduction of weight, space consumption and noise compared to state of the art actuator-motor systems. MASA thereby increases the benefits for end-users and opens new opportunities for innovative applications that cannot be realised yet with conventional systems. The market analysis revealed that especially the German OEMs Daimler, VW and BMW are suitable for an entry market of a lumbar support adjustment system with MASA. The entire potential on the markets North America, Western and Central Europe and China is about 20 million cars per year. At present, Magna equips 1,5 million cars per year with front seats including a lumbar support system but the sale figures are expected to be significantly higher, since the license can be sold to other seat or lumbar support system suppliers. The costs for the development are about 200.000 Euros and were calculated by experts. Additionally, about 45.000 Euros are needed to file a patent. The cost evaluation is based on the assumption, that the idea will be exploited in form of a license sale, since Magna Seating has no in-house production of lumbar support adjustment systems yet. In order to avoid any problems with legal requirements, the functional security process regarding ISO 26262 has to be followed. To test and demonstrate the technical functioning, a team of experts constructed a conceptual model. A deflection of 8mm could be reached, what means 4,5cm of deflection projected to a real car seat system. State of the art systems have an adjustment range of 2,5cm. With Smarter Alloys and Nimesis two promising suppliers could be identified and a first contact provided helpful information regarding the design of the real size seat model in future.

The realisation of the idea now mainly depends on the decision of the management and represents the next step in the innovation process.

5.2 Outlook and Recommendations

As mentioned above, the work represents a fundamental basis for further decisions regarding the implementation of MASA. However, it must be mentioned that the results are largely based on the subjective assessments of the project team and were supplemented by experts. Thus, the results should definitely be refined and completed if it comes to a realisation of the project and the related increase in the use of capital and people. In relation to the lumbar support adjustment system, tests for heat dissipation, reliability, durability and operational stability must be performed on a full-size seat. With a full-size prototype, it would be possible to demonstrate the complete functionality, including a control system. This requires the design of a control system for either an incremental or a continuous operation.

It can be seen that the analysis mainly relates to the application of MASA for a lumbar support adjustment system, as a synergy with Magna Seating seems most likely. In order to increase the chance of the realisation of MASA, involving other potential partners is recommended, whether internal or external. One possibility would be cooperation with Magna Mirrors and Closures, since this application uses many displacement adjustment mechanisms with a small displacement range (rear spoiler adjustment, rear view mirror adjustment, trunk locking mechanism, mirror control system, ventilation flap adjustment, etc....).

No patent filing has been carried out yet. However, the patent research has shown a trend for the use of SMA for innovative adjustment systems. Therefore, a patent application should be filed as soon as possible.

During the project, it was possible to establish contact with two companies that deal with the production and processing of SMA. The two companies already provided the project team with valuable information about the technological development. These contacts should be deepened in order to ensure that no problems arise regarding suppliers.

It is recommended to try to integrate MASA in projects where space and weight but also noise reduction play a significant role. The aim is to develop multi-functional seats, with minimal space and weight consumption. Thus, the project aims overlap with the generated benefit by MASA. In addition, the creation of new projects would not be necessary, which could have advantages for the financing.

The cost evaluation is based on a license sale of the MASA technology in the form of a lumbar support adjustment system, since Magna Seating does not produce such systems in-house. Nevertheless, a start-up of production is conceivable and therefore a cost analysis including development costs for production systems as well as for the product costs would be necessary in order to estimate possible profits.

6 List of References

Auricchio, F, Faravelli, Z, Magonette, G & Torra, V 2001, *Shape memory alloys advances in modelling and applications*, International Center for Numerical Methods in Engineering, Barcelona.

Bhattacharya, K 2003, *Microstructure of martensite*: *why it forms and how it gives rise to the shape-memory effect*, Oxford University Press, Oxford.

Brockhoff, K 1992, *Forschung und Entwicklung, Planung und Kontrolle*, 3rd edn, Oldenbourg, München.

Brooke, M.Z, Mills W.R 2003, *New product development: successful innovation in the marketplace*, International Business Press, New York.

Bühner, R 2004, *Betriebswirtschaftliche Organisationslehre*, 10th edn, Oldenbourg Verlag, München.

Cooper, R.G 2010, *Top oder Flop in der Produktentwicklung: von der Idee zum Launch*, 2.nd edn, Wiley-VCH Verlag, Weinheim.

Disselkamp, M 2012, *Innovationsmanagement Instrumente und Methoden zur Umsetzung im Unternehmen*, 2nd edn, Springer Gabler, Wiesbaden.

Drucker, P.F 2007, *Innovation and entrepreneurship: practice and principles,* Butterworth-Heinemann, Amsterdam; London.

Fischer, M 2001, *Produktlebenszyklus und Wettbewerbsdynamik: Grundlagen für die ökonomische Bewertung von Markteintrittsstrategien*, Gabler, Wiesbaden.

Gassmann, O & Sutter, P 2008, *Praxiswissen Innovationsmanagement*, Hanser Verlag, München.

Gaubinger, K, Werani, T & Rabl, M 2008, *Praxisorientiertes Innovations- und Produktmanagement: Grundlagen und Fallstudien Aus B-to-B-Märkten*, Gabler, Wiesbaden.

Gelbmann, U, Leitner, W, Perl, E, Primus, A & Ritsch, K 2003, *Innovationsleitfaden: der Weg zu neuen Produkten*, Self-published, Graz.

Hansmann, K.W 2006, *Industrielles Management*, 8th edn, Oldenbourg Verlag, München.

Hauschildt, J 1993, I*nnovationsmanagement*, Vahlen, München.

Heesen, M, 2009, *Innovationsportfoliomanagement: Bewertung von Innovationsprojekten in kleinen und mittelgroßen Unternehmen der Automobilzulieferindustrie*, Gabler, Wiesbaden.

Hillenbrand, M 2011, *Funktionale Sicherheit nach ISO 26262 in der Konzeptphase der Entwicklung von Elektrik/Elektronik Architekturen von Fahrzeugen*, KIT Scientific Publishing, Karlsruhe.

Horsch, J 2003, *Innovations- und Projektmanagement: von der strategischen Konzeption bis zur operativen Umsetzung*, Gabler, Wiesbaden.

IHS AutoInsight, Light Vehicle Sales Forecast, January 2013.

Issler L % Häefele P 2003, *Festigkitslehre: Grundlagen, 2nd edn, Springer, Berlin; New York.*

Kajiwara K & Osada J 2001, *Gels handbook: the fundamentals,* Academic Press, San Diego.

Keßler, H & Winkelhofer, G 2004, *Projektmanagement: Leitfaden zur Steuerung und Führung von Projekten,* Springer Verlag, Wien.

King, N & Anderson, N 1995, *Innovation and change in organizations*, Routledge, London.

Koch, J 2004, *Marktforschung: Begriffe und Methoden*, Oldenbourg Verlag, München.

Litke H.D & Kunow, I 2006, *Projektmanagement*, 5th edn, Haufe-Lexware, Planegg.

Lendlein, A & Behl, M 2010 (eds), Advances in polymer sience, vol. 226, *Shape-memory polymers*, Springer, Berlin.

Litke, H.D 2007, *Projektmanagement: Methoden, Techniken, Verhaltensweisen, Evolutionäres Projektmanagement*, 5th edn, Hanser Verlag, München.

Macharzina, K 1995, *Unternehmensführung das internationale Managementwissen: Konzepte - Methoden – Praxis, 2nd* edn, Gabler, Wiesbaden.

Meffert, H 1998, *Marketing: Grundlagen marktorientierter Unternehmensführung*, 8th edn, Gabler, Wiesbaden.

Nagl, A 2011, *Der Businessplan: Geschäftspläne professionell erstellen*, 6th edn, Gabler, Wiesbaden.

Oelsnitz, D 2009, *Management: Geschichte, Aufgaben, Beruf*, Beck, München.

Pepels, W 2004, *Marketing*, 4th edn, Oldenbourg Verlag, München.

Pepels, W 2006, *Produktmanagement: Produktinnovation, Markenpolitik, Programmplanung, Prozessorganisation*, 5th edn, Oldenbourg Verlag, München.

Pleschak, F & Sabisch, H 1996, *Innovationsmanagement*, 3rd edn, Schäffer-Poeschel, Stuttgart.

Porter, M.E 1998, *Competitive advantage: creating and sustaining superior performance, Free* Press, New York.

Pritzker, S.R & Runco M.A 1999, *Encyclopedia of Creativity*, Academic Press, San Diego.

Sabisch, H 1991, *Produktinnovation*, Poeschel, Stuttgart.

Schäppi, B, Andreasen, M.M, Kirchgeorg, M & Radermacher, F.J 2005, *Handbuch Produktentwicklung*, Hanser Verlag, München.

Schumpeter, J.A 1952, *Theorie der wirtschaftlichen Entwicklung: eine Untersuchung über Unternehmensgewinn, Kapital, Kredit, Zins und Konjunktur,* 5th edn, Duncker & Humblot, Berlin.

Schwetje, G, Vaseghi, S 2005, *Der Businessplan*, 2nd edn, Springer, Berlin.

Seghezzi, H.D 1994, *Qualitätsmanagement: Ansatz eines St. Galler Konzepts: integriertes Qualitätsmanagement,* Schäffer-Poeschel, Stuttgart; Zürich.

Seibert, S 1998, *Technisches Management: Innovationsmanagement, Projektmanagement, Qualitätsmanagement*, Teubner, Stuttgart.

Simon, H, Gathen, A 2010, *Das große Handbuch der Strategieinstrumente: Werkzeuge für eine erfolgreiche Unternehmensführung*, 2nd edn, Campus Verlag, Frankfurt am Main.

Specht, G, Beckmann, C 1996, *F- & -E-Management*, Schäffer-Poeschel, Stuttgart.

Stöckel, D, Hornbogen, E, Ritter, F, Tautzenberger, P 1988 (eds), *Werkstoffe, vol. 259, Legierungen mit Formgedächtnis: Industrielle Nutzung des Shape-Memory-Effektes* Grundlagen, Werkstoffe, Anwendungen, Expert Verlag,

Straßberger, F, Beise, M, Belitz, H 1996, '*F&E-Aktivitäten, Außenhandel und Wirtschaftsstrukturen: Die technologische Leistungsfähigkeit der deutschen Wirtschaft im internationalen Vergleich*', Beiträge der Strukturforschung, vol. 165, V. Deutsches Institut für Wirtschaftsforschung, Berlin.

Strunz, H, Dorsch, M 2001, *Management*: *Managementwissen für Studium und Praxis*, Oldenbourg Verlag, München; Wien.

Thom, Norbert 1980, *Grundlagen des betrieblichen Innovationsmanagements*, 2nd edn, Hansstein, Königstein.

Töpfer, A 2007, *Betriebswirtschaftslehre: Anwendungs- und Prozessorientierte Grundlagen*, 2nd edn, Springer, Berlin; Heidelberg.

Trommsdorff, V, Steinhoff, F 2007, *Innovationsmarketing*, Vahlen, München.

Trott, P 2005, *Innovation management and new product development*, 3rd edn, Financial Times Prentice Hall, Upper Saddle River.

Tsifidaris, M, 1994, *Management der Innovation*, expert Verlag, Renningen-Malmsheim.

Vahs, D, Burmester, R 1999, *Innovationsmanagement: von der Produktidee zur erfolgreichen Vermarktung*, Schäffer-Poeschel, Stuttgart.

VDI-Gesellschaft Produkt- und Prozessgestaltung 2011, *Wertanalyse: Das Tool Im Value Management*, 6th edn, Springer, Berlin.

Wayman, C.M, Otsuka, K 1999, *Shape memory materials*, Cambridge University Press, Cambridge; New York.

Witte, H, 2007, *Allgemeine Betriebswirtschaftslehre: Lebensphasen des Unternehmens und betriebliche Funktion*, Oldenbourg Verlag, München.

Wohinz, J.W 1983, *Wertanalyse – Innovationsmanagement*, Physica-Verlag, Würzburg; Wien.

Zangemeister, C 1976, *Nutzwertanalyse in der Systemtechnik: eine Methodik zur multidimensionalen Bewertung und Auswahl von Projektalternativen*, 4th edn, Wittemann, München.

7 Web links

GS-batteries, viewed 27 May 2013, http://www.gs-battery.com/wp-content/uploads/2012/12/GS_Catalogue.pdf.

Joachim Strittmatter n.d., Formgedächtnis-Aktoren in der Fahrzeugsicherheitstechnik und Alterungsverhalten von NiTi, viewed 5 December 2012, http://www.koord.hs-mannheim.de/Formgedächtnis_Strittmatter.pdf.

Magna International Inc., viewed 19 April 2013, http://www.magna.com/de/.

Memry, viewed 19 February 2013, http://www.memry.com.

Nimesis, viewed 19 February 2013, http://www.nimesis.com/en.

Smarter Alloys, viewed 19 February 2013, http://www.smarteralloys.com.

Winning Innovations, viewed 20 April 2013, http://www.win.magna.com.

8 List of Figures

9 List of Tables

10 List of Abbreviations

ASIL	Automotive Safety Integrity Level
°C	Degrees Celsius
C	Controllability
E	Exposure
ISO	International Organization of Standardization
K	Kelvin
Magna International Inc.	Magna International Incorporated
MASA	Mechatronic Adjustment System Automotive
OEM	Original Equipment Manufacturers
R&D	Research and Development
S	Severity
SCC	Shape Changing Capability
SCP	Shape Changing Polymers
RF	Shape Fixity Ratio
SMA	Shape Memory Alloys
SMC	Shape Memory Ceramics
SME	Shape Memory Effect
SMM	Shape Memory Materials
SMP	Shape Memory Polymers
RR	Shape Recovery Ratio
WIN	Winning Innovations

Appendix A

Business Plan
Executive Summary

MASA-Mechatronic Adjustment System Automotive

Version 4

Stand 7.6.2013

MAGNA

WINNING INNOVATIONS WIN BY MAGNA

Objective

The aim is to evaluate the technical feasibility and the economic potential of Mechatronic Adjustment System Automotive (MASA). MASA is a product idea that originated from the Magna internal idea generation program WIN.

The Idea

Reinhard Brandstätter and Vladan Stevanovic came up with the idea of using the special properties of Shape Memory Alloys (SMA) in Car Adjustment Systems and called it “Mechatronic Adjustment System Automotive” (MASA). Nitinol, a nickel titanium alloy, has especially promising material properties. Nitinol can, when treated in the right way, change its shape on demand, even under high load. The shape changing effect reacts to temperature changes but can also be triggered by electricity. The application of this alloy makes the realisation of targeted longitudinal movement and torsion possible. Thus it enables the substitution of traditional adjustment systems using gears and motors or other actuator systems

Unique selling proposition

The significant advantage of MASA is the simultaneous reduction of weight, space and noise compared to state of the art actuator-motor systems. MASA thereby increases the benefits for end-users and opens new opportunities for innovative applications that cannot yet be realised with conventional systems.

Market potential and target customers

First and foremost, the entire automotive market can be seen as a potential market. Even applications of MASA on other markets would be conceivable. In particular, the market potential for a lumbar support adjustment system with MASA technology is about 20 million cars per year. From a regional point of view, North America, China and Europe represent the most promising markets.

For MASA in general, it is not possible to define target customers. For a lumbar support adjustment system, however, the complete luxury car segment can be considered, as well as all middle-class vehicles and vans, which are usually high mileage driven.

Current project status

Currently, a technological and economic feasibility study has been conducted. Additionally, it was possible to show the functionality of MASA with a first conceptual model, without a control system.

Next steps

In relation to the lumbar support adjustment system, tests for heat dissipation, reliability, durability and operational stability must be performed on a full-size seat prototype.

To increase the chance of the realisation of MASA, it is recommended that other potential partners are involved, whether internal or external, which use displacement adjustment mechanisms with a small displacement range for their products.

A patent application should be filed as soon as possible.

The existing contacts with possible suppliers should be deepened in order to ensure that no problems arise from the supply side.

It is recommended that MASA is to be integrated in projects where space and weight but also noise reduction plays a significant role. This could be an existing seat project, like Stow-in-floor or Free2Stow.

The cost evaluation is based on a license sale of the MASA technology, in form of a lumbar support adjustment system, since Magna Seating does not produce such systems in-house. Nevertheless, a start-up of production is conceivable and therefore a cost analysis, including development costs for production systems as well as for the product costs, is necessary in order to estimate possible revenue.

Appendix B

Business plan

MASA-Mechatronic Adjustment System Automotive

Version 2

Stand 7.6.2013

Table of content

1 Business concept

1.1 Problem solution

1.1.1 Which problem does the innovation solve?

The demanding behaviour of western society forces industry to come up with new features and to improve existing ones. Car seats for luxury cars have, in most cases, more than ten electric motors and actuators to drive the adjustment applications. The high number of adjustment possibilities and other additional comfort features, like massage functions satisfy, on the one hand, the high expectations of the customers but cause significant additional problems. With an increase in comfort, the seats become bigger and heavier. Almost no space is left to incorporate new functions. Customers complain about very little legroom and the noise of the motors is considered undesirable. The weight of the seats contributes to a great extent to the overall weight of a car and therefore also to the fuel consumption. With Mechatronic Adjustment System Automotive (MASA), it is possible to replace motors and actuators by just one wire. In other words, with MASA it is possible to solve all the arising problems with just one solution.

1.1.2 Fulfilled customer needs

The following points give examples of how MASA increases the benefit for customers:

- *Cost reduction:* The assembly is easier and requires fewer steps. The adjustment system consists of a small number of parts.
- *New possibilities for adjustment applications:* Due to low space requirements and the low weight, new features can be added to car seats that have not been possible yet.
- *Functional reliability:* The use of a few robust components increases functional reliability (no valves, motors, actuators, bladders or tubes are needed).
- Resistance against environmental effects like humidity (Nitinol shows a high corrosion resistance).
- *Simple and flexible design:* Complicated gear mechanism does not have to be taken into consideration. Thus, the design is flexible and simple.
- *Fewer commodities are needed:* Especially fewer electro-magnetic components are needed.

1.1.3 Quantifiable benefit

For the OEM

- *Weight reduction:* The new technology reduces the weight significantly. Lighter wires replace electric motors and gear mechanism (a weight reduction of up to 35% is possible by replacing the conventional lumbar support adjustment system with the MASA technology).

For the end-user

- *Noise reduction:* The noise reduction represents a significant advantage, since it represents a main problem in traditional solutions that can hardly be solved with an electric motor and gear mechanism or an air bladder system. The MASA system does not create any noise at all.

For the end-user and the OEM

- *Space reduction:* The width of traditional lumbar support adjustment systems exceeds 30mm. With the new technology, it is possible to reduce the width down to less than 10mm.

1.2 Range of offers

1.2.1 Description of the technology

Magna decided to establish an idea generating platform with the name “Win - winning innovations” to support the traditional idea creation processes. MASA is one of those ideas, which made it through the selection procedure and is now investigated in more detail.

The intention of MASA is to use the special properties of Shape Memory Alloys (SMA) in car adjustment systems. SMA have the ability to memorise a certain shape and change it on demand, triggered by external stimuli such as heat, light, magnetic fields, or electricity. NiTi alloys with a nickel content of about 50% (atoms) are the most common alloys in technical applications, since they exhibit excellent results in terms of memory behaviour. A non-plastic deformation of maximum 8% is possible. Additionally, it is possible to repeat the cycle under certain conditions even more than one million times. The application of this alloy makes the realisation of targeted longitudinal movement and torsion possible. Thus, it enables the substitution of traditional adjustment systems using gears and motors or other actuator systems with just one wire. In the case of MASA, the trigger is electricity that heats up the wire and causes the deformation. Figure 1.1 shows the functioning.

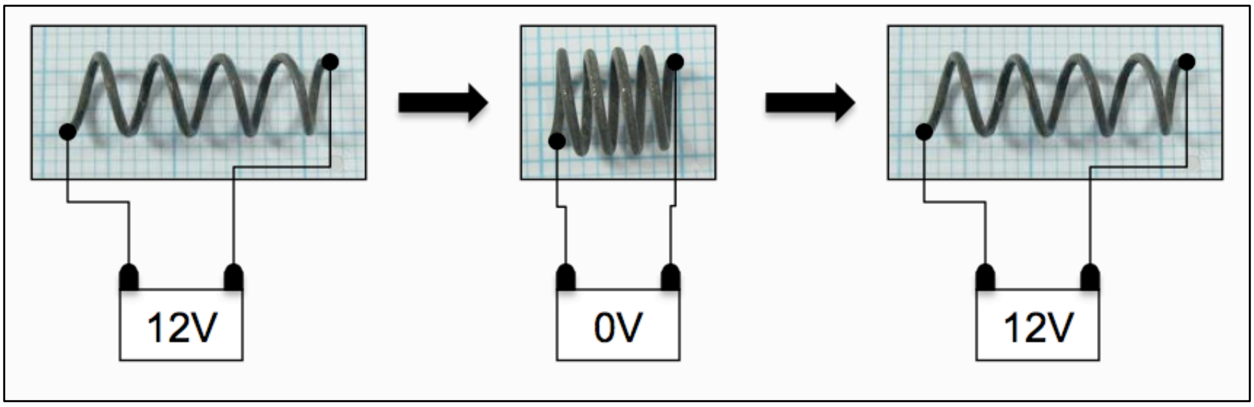

Figure 1.1: Functioning of MASA (referring to an internal report of Magna)

If the ends of the wire are fixed, the wire is hindered from deforming and thus generates great force. This force is then used to generate deflection.

1.2.2 Fields of application

In principle, the use of the technology is possible in all fields where a translational or rotational movement or a combination of both is required. Thus, also non-automotive applications can be realised with MASA. However, the displacement range obtains a limitation, which is limited due to the maximum strain of the material. As an initial step, MASA will be used for seat features, since Magna Seating already shows interest in the technology. Massage functions in the backrest and the cushion, side bag adjustment systems, lumbar support adjustment systems, massage function in the armrest or adjustable headrests are conceivable. Figure 1.2 shows possible applications for a car seat.

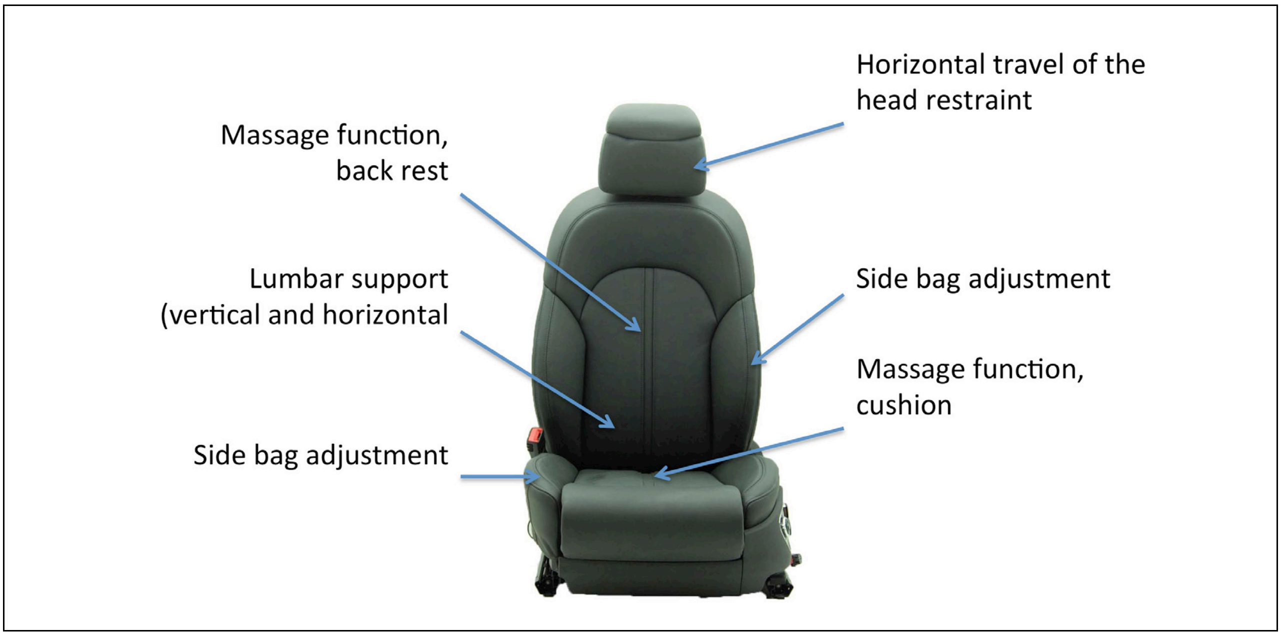

Figure 1.2: Application possibilities for a car seat (own illustration)

Massage functions using SMA seem to be especially promising. A network of SMA wires would allow a high number of massage options with minimum space consumption.

As a second step, MASA can be used for applications in the entire vehicle. Table 1.1 shows other applications that could be implemented in the future with a MASA system.

• Window lift system	• Adjustment system of the rear lift gate
• Locking mechanism for the fuel inlet	• Windshield wipers control system
• Locking mechanism for car doors	• Pedal height control
• Sliding roof mechanism	• Steering wheel adjustment system
• Ventilation flap adjustment system	• Rear view mirror adjustment system
• Mirror control system	• Trunk locking mechanism
• Adjustment system for bending lights	

Table.1.1: Application possibilities for the entire car (own illustration)

1.2.3 The innovation

The idea to use SMA is not new. For several years, the material is used for innovative products and has become increasingly popular. SMA sheets, for instance, are used for ventilation flaps and SMA wires are successfully used in dental technology.

The innovation of MASA is the use of SMA as a replacement for motor and actuator in applications where rotational and translational motion has to be generated. The electric control of the strain is especially new so that the wire acts like a servomotor.

1.2.4 Stage of development of the product

A team consisting of employees of Magna Seating, Magna International and Burg Design has been working on the project since November 2012. The intention is to replace the traditional motor and the actuator system or an air bladder system of a lumbar support adjustment system with the new technology. In January, the first conceptual model was completed, which was installed in a miniature seat, provided by Magna Seating. With this conceptual model, the basic mode of operation can be tested. In other words, the deflection as a function of contraction can be generated. The heating of the wire is already generated with electricity but cannot be controlled yet. Conceptual model one achieves a horizontal deflection of 8mm. Projected to a normal seat, this means 4cm of deflection. At present, lumbar adjustment systems require an adjustment range of 2.5cm. In Figure 1.3 the conceptual model one is shown.

As the next step, a prototype will be developed that can be installed in a proper car seat. Also, a servo operation should be possible with a respective control system.

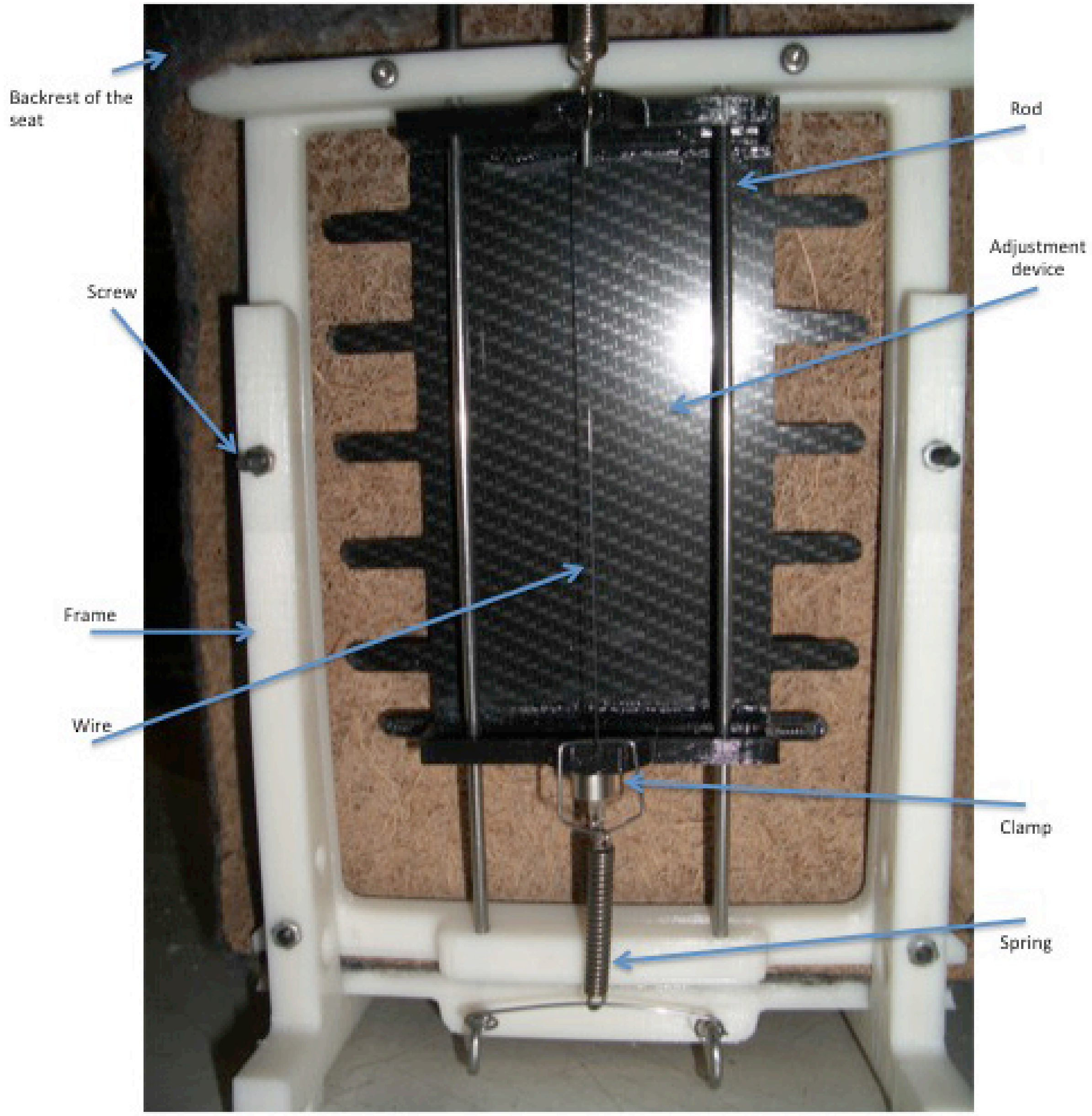

Figure 1.3: Conceptual model one (own illustration)

1.2.5 How to reach market maturity

An exact time for the market entry cannot be set at that moment. The time-to-market also depends heavily on the deployment of staff and resources involved. In principle, there are several ways to reach the market. At the closest fit is a licence sale of the technology. That means the lumbar support adjustment system will be developed but not produced in-house. In this case, the development must be either fully completed, or a customer buys a half developed idea and finishes the development. In the second case, a prototype that demonstrates the functionality would be enough to reach patent maturity. Another possibility is to carry out the complete development and production in-house. However, this is unlikely because Magna has never produced lumbar support adjustment systems itself before and shows no intention to start production in the future.

In any case, a series of tests must be performed to reach market maturity. These have to be carried out on a prototype, installed in original size car seat. The developed system must be subjected to the following tests:

- Current test (can the battery provide enough power)
- Heat dissipation (heat generation must not affect the occupants in any case)
- Lifetime (especially the number of cycles the material withstands cannot be assessed with certainty without testing)
- Motion test (the motion sequence must be set in a way it generates the greatest possible comfort to the occupant)
- Adjustment range (it needs to be tested whether the adjustment range meets the minimum requirements)
- Power development (it has to be tested whether the sufficient force is generated since a lever system is used)
- Testing for operational safety (as the wire heats it must be ensured that this will not impact on operational safety negatively)
- Functional stability (endurance test, durability test, pulsator test)
- Environmental influence (climate test, tropic test, heat exchange test, heating cooling test)

1.3 Life cycle

1.3.1 Product life cycle

Since MASA is an innovative product and has not been put on the market yet, MASA is before the launch phase in terms of the product life cycle. Therefore, it is difficult to make assumptions about the future development. Only after the introduction of the product to the test market, findings can be derived. However, a long product life cycle can be expected, as the development for new actuator systems is relatively slow and secondly, the market saturation can be repeatedly delayed with the use of MASA for various future applications.

1.3.2 Possibilities for further development

For further development, there are basically two options. Firstly, the new multi-way technology of Smarter Alloys can be used to develop a simple and cost-effective incremental adjustment system. The use would be especially feasible for mid-size cars, replacing the manual systems and for projects where space plays a major role (Stow-in-floor, Free2Stow). Secondly, a system with continuous control can be achieved with a correspondingly more complex control system that also offers more comfort. At the moment a solution under continuous current is being considered for both methods.

Additionally, a solution with a locking system in order to preserve the electrical system and to increase the reliability is conceivable. Such a system only needs current until desired deflection is reached. The locking mechanism holds the device in position.

After a successful market launch beside Nitinol other SMA can also be considered. Copper based SMA, for instance are significantly cheaper.

1.4 Imitation

1.4.1 Uniqueness of the product

The uniqueness of the product lies in the replacement of actuator and motor of adjustment systems by a cheaper, lighter, noiseless and more reliable SMA system.

1.4.2 How can the innovation be protected?

Patent protection of the idea should be achieved as quickly as possible, since it can be assumed that other companies are working on the realisation of adjustment systems with SMA. A patent research has revealed that companies such as Faurecia and Legget & Platt already use SMA as a partial replacement of the actuator and motor.

The patent may initially only be registered in Germany. From the filing date, there is an 18-month protection period. In this phase, the patent may be extended if the development to market requires product changes with respect to the functionality. Furthermore, the market analysis gives information about the countries where the patent should be filed subsequently, within the twelve-month period, in which countries can be declared in retrospect. The estimated patent costs can be looked into in chapter 5.2.

1.4.3 Legal requirements

Together with an expert from Magna Steyr, it was found that a lumbar support adjustment system in general does not need to be the subject of an authorisation procedure. However, an obvious risk for occupants cannot be present. In addition, the lumbar support adjustment system includes electronic components and it must therefore be tested according to ISO 26262, a standard for the verification of the functional safety of electronic components for road vehicles with a weight not exceeding 3.5 tonnes.

ISO 26262 includes the evaluation of hazards, with the help of the so-called ASIL (Automotive Safety Integrity Level) level that is built on the three indicators, severity, control, and exposure. The higher the ASIL level, the stricter the security requirements.

The ASIL has to be evaluated separately for each failure that could possibly occur. The project team identified three possible failures regarding the electronic components.

- *Accidental deflection of the system:* The system no longer responds to the user and performs arbitrary displacement. This failure does not represent any hazard to the end-user. No action has to be taken.
- *The wire heats up without control:* The wire is heated up by the means of electric power. If the heating is out of control, the wire could reach very high temperatures and cause a fire. The expert rated this failure as ASIL A-B (E4: can happen any time, S1-2: small to possibly fatal injury if the wire causes a fast progressing fire, C1-2: easy manageable - lean forward, pull the car over, freeing other car occupants). ASIL A-B represents a low security level. However, in order to avoid any problem during this functional security process, it is important to take action. The expert suggests using an incombustible material to insulate the wire.
- *The electronic control system causes fire:* The same applies here as to a wire without control. No problems should occur during the functional security process if sufficient insulation is kept in mind.

2 Market

2.1 Market overview

2.1.1 Market potential and market volume

It is difficult to make a serious statement about the overall market potential of MASA, since the application potential goes far beyond the automotive market. Thus, in the following discussion, the statements about the market potential are limited to a lumbar support adjustment system.

Other than initially assumed, lumbar support adjustment systems are used not only in luxury cars but already in mid-size cars and cars with high mileage. Such cars are, for example, typical company cars like the Audi A4 or the BMW 3-Series, as well as light commercial vehicles, such as the VW Transporter or the Mercedes Sprinter. Based on sales forecasts and the acquired knowledge from experts, the internet and literature the total market potential for 2014 to 2017 is approximately 16 to 20 million cars. Per car, usually two lumbar support adjustment systems are installed, so that the market potential refers to 32 to 40 million lumbar support adjustment systems per year. However, a full exploitation of the market potential is unrealistic due to the strong competition with other car seat producers. Referred to Global Insight, 81,5 million cars were produced in 2012 and Magna equipped 5% of these cars with front seats. Subsequently 30% of these seats were equipped with a lumbar support adjustment system, which corresponds to 1,2 million cars in 2012.

2.1.2 Success factors and purchasing motives

The following success factors and purchasing motives could be identified:

- Huge range of application possibilities
- The combination of noise, weight and space reduction
- Image increase due to the innovative approach
- Increase in comfort
- Cost reduction due to the leaf-out of expensive parts like the motor and the actuator
- Increase of functional safety, since the innovative system needs less and robust parts
- Applicable to already existing projects (Stow-in-floor, Free2Stow)

2.1.3 Market influencing factors

- Level of acceptance of the OEMs and end-users
- The technological implementation of the idea
- Possible competitors
- The global economic situation
- The price of the product

2.2 Market segmentation

2.2.1 The most important market

The most important market of MASA is clearly the automotive market. The car seat market is particularly important, since cooperation already exists. As well as the lumbar support adjustment system, there are many other car seat applications where the development work can be incorporated to a large extent. Regionally, the most important markets are North America, Europe and Asia due to the high sales of eligible types of cars.

2.2.2 The profile of the customers

To set a profile of the target customer for the MASA technology in general is not possible. For a lumbar support adjustment system, two target groups have to be distinguished. On the one hand, there are upper class segment customers, who demand the highest standards of comfort. On the other hand, there are customers in the mid-range segment that place due to high use of cars much emphasis on seat comfort.

2.2.3 Who represents the target group

As the target group for a lumbar support adjustment system, all OEMs come into consideration that sell cars on the above mentioned target markets. Furthermore, in the case of license sales, all suppliers of lumbar support adjustment systems are potential customers. For MASA in general, additionally Magna internal groups such as Magna Mirrors and Closures represent target groups.

2.3 Market entrance

All considerations regarding market entrance are referred to a lumbar support adjustment system.

2.3.1 Strategy of market entrance

The market entry should be realised through a pilot market in order to minimise the still high risk of failure. The German OEMs VW, Daimler and BMW represent the ideal partners for the market launch of lumbar support adjustment systems, due to the already existing relationships, the high sales figures of cars that meet the customer type and the regional proximity. The pilot market focuses on the luxury car segment, since in most cases, new technologies are first applied for this car type. The potential of entry market can be seen in Figure 2.1 Mercedes and BMW have especially high sales figures for luxury cars but also VW and Audi (belongs to VW) cannot be neglected due to their high presence on the middle class sector.

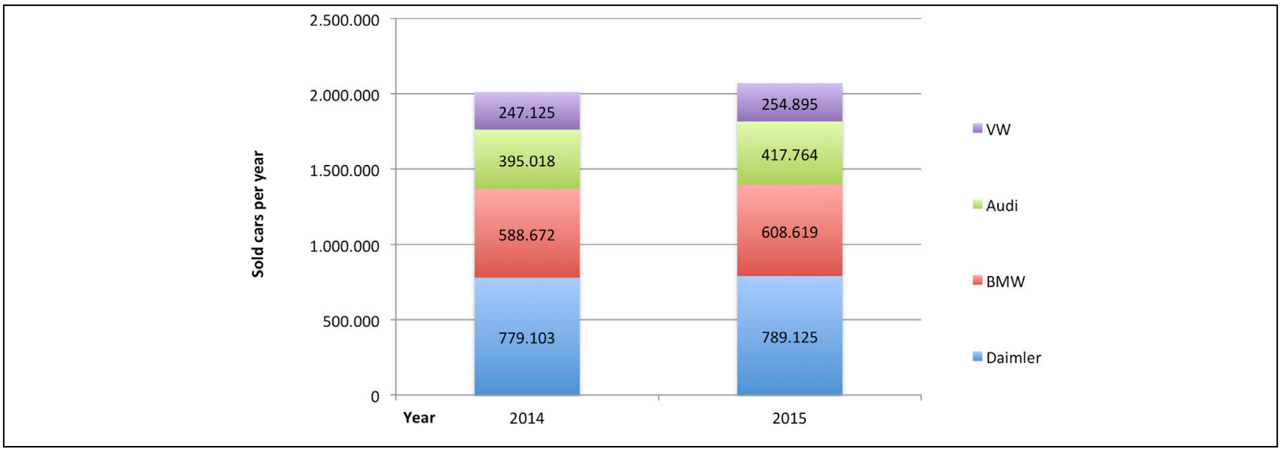

Figure 2.1: Market potential of the pilot market (own illustration)

After successful market entry via the luxury car segment, the German OEMs will also use the technology for promising mid-size cars. Finally, the full market potential can be deployed with the help of the already gained acceptance. In the case of a license sale this means that lumbar support producers do not just produce for Magna but also for other front seat manufacturer. If Magna would produce lumbar support adjustment systems in-house, the systems could be used directly or sold to other seat manufacturer, which need to buy lumbar support adjustment systems externally. The total market potential is shown in Figure 2.2.

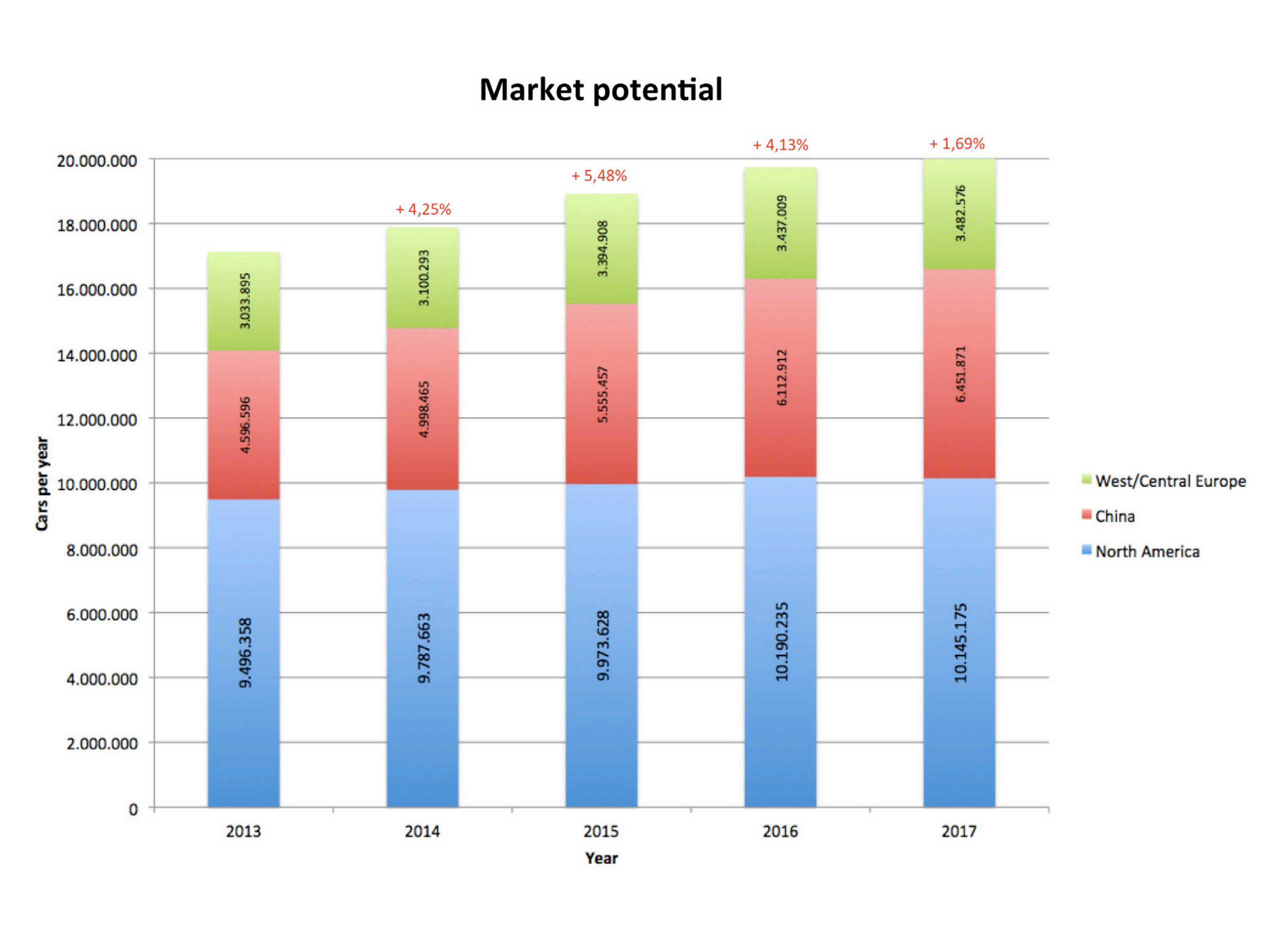

Figure 2.2: Total market potential (own illustration)

2.3.2 Price-place-promotion

Price

For MASA in general, no price can be defined. For the lumbar support adjustment system, however, the price is dependent on the competition, the production costs, the investment costs and the price of the previous models. Furthermore, the higher utility value has a positive effect on the target price. Nevertheless, at the moment, no reliable statement can be made about the price because the costs and the pressure of competition cannot be fully assessed yet.

Place

Basically, worldwide use of the technology in a variety of industrial fields is possible. Attention has to be paid to the automotive market in Europe, Asia and North America.

Promotion

In respect to the lumbar support adjustment system, it makes sense to present the innovative technology at auto shows in order to attract the attention of both OEMs and end-users. In the case of a license sale, the product could be demonstrated to lumbar support system manufacturers with the help of a fully operational prototype. End-users can be informed about the new technology with relevant magazines. This increases the acceptance in advance and the consumer exerts a certain pressure on the OEMs by demanding the new technology.

3 Competition

3.1 Similar technologies

This chapter describes technologies that are used at present for lumbar support adjustment systems. These technologies can be seen as potential competitors, since most future products will be further developments.

3.1.1 Air bladder system

In such systems, the lumbar support adjustment is realised by an air bladder. The air bladder is connected to one or more hoses and a valve system. A pump supplies the system with air (it could also be any other fluid). The flow is controlled by the valve system. In many cases, the bladder that serves the lumbar support is just one of many bladders. The user can control all bladders separately, which leads to a large number of adjustment possibilities and a high degree of adjustability. Currently, Faurecia, Legget & Platt, and Magna use or produce the air chamber system. Johnson Control has filed patent applications that contain such a pneumatic system. The air chamber system of an Audi A8 (model 2011) is illustrated in Figure 3.1 and Figure 3.2.

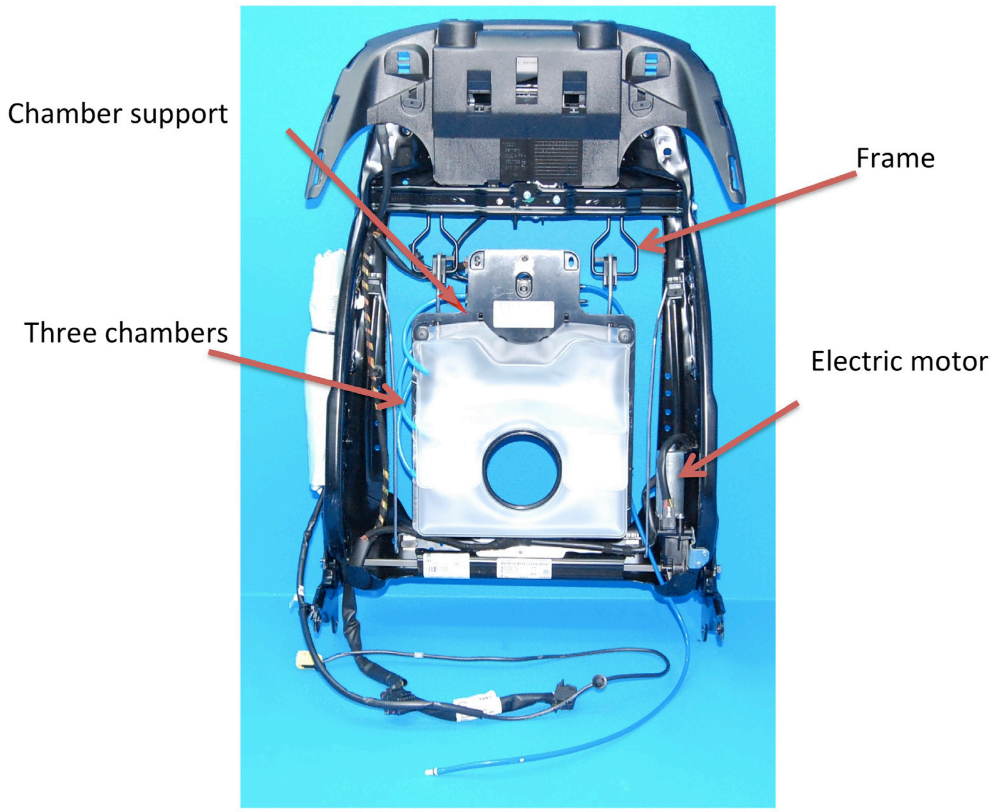

Figure 3.1: Air chamber system, front view (referring to an internal report of Magna)

The picture in Figure 3.2 shows the three separate chambers that create high adjustability. Furthermore it shows the electric motor, the frame and the chamber support.

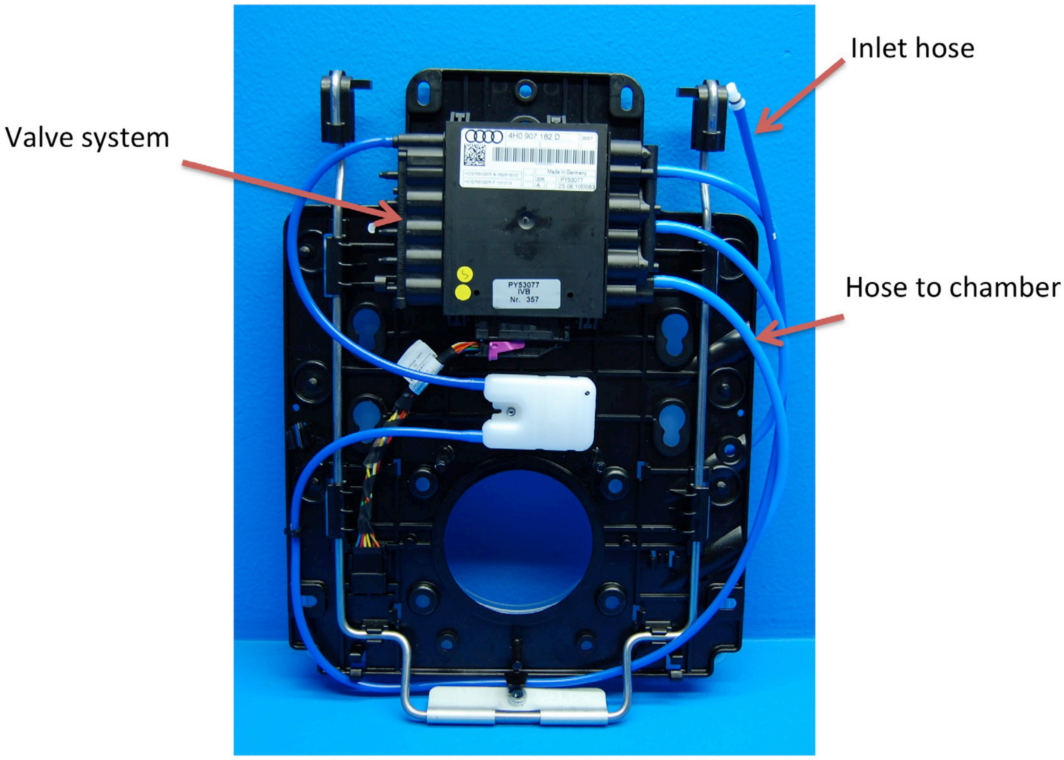

Figure 3.2: Air chamber system, rear view (referring to an internal report of Magna)

The picture in Figure 3.2 shows the relatively complex valve system, the inlet hose and the hoses that feed the chambers.

3.1.2 Motor-actuator system

In principle, such systems always operate with an engine and an actuator. The engine drives the actuator that converts the rotational movement into a translatory motion. This translational movement leads either directly to the deflection of the lumbar adjustment or moves a further mechanism (the deflection tightens a cable that in turn presses the adjustment device in the direction of the occupant). Leggett & Platt and Magna use such systems.

Figure 3.3 shows an engine-actuator system for an Audi A8 (model 2006).

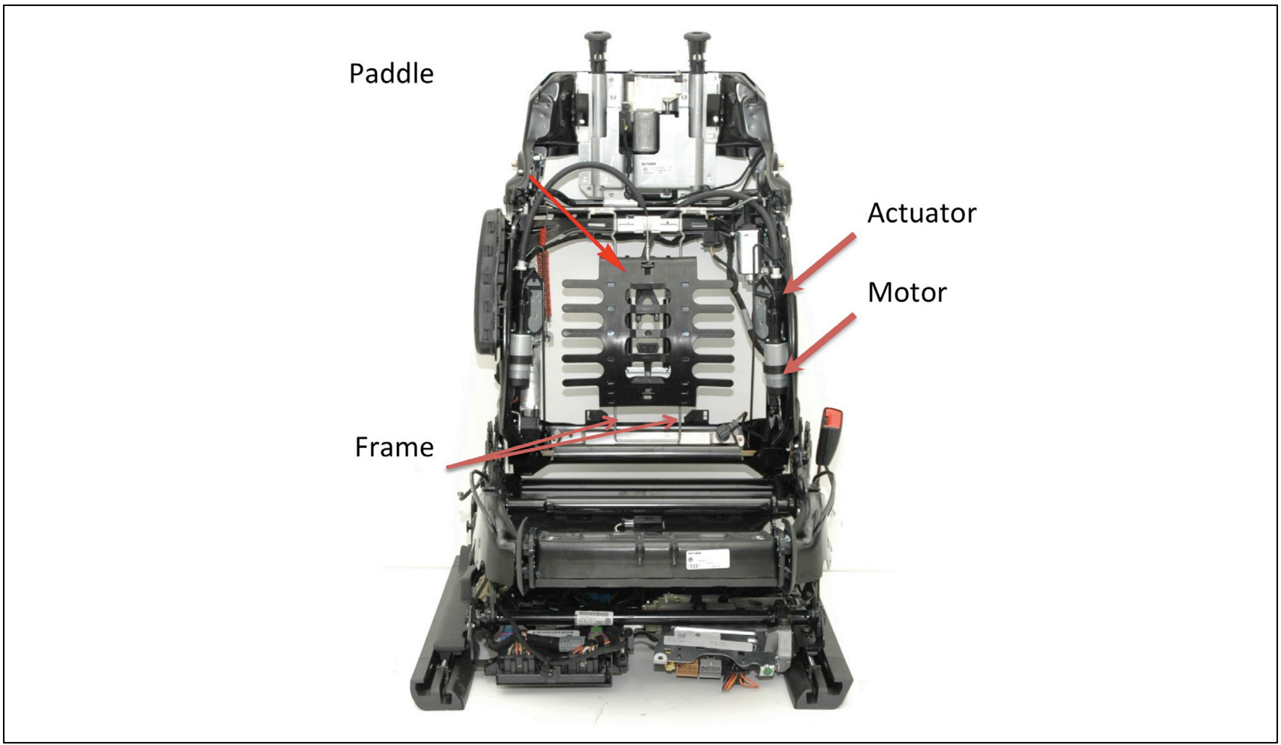

Figure 3.3: Motor-actuator system (referring to an internal source of Magna)

These systems have usually a depth of more than 40mm, since the actuator and the motor need a certain diameter. At present, the weight is also relatively high.

3.1.3 Manual system

Manual systems operate in the same way as motor-actuator systems but he motor is replaced by a manual rotation of a knob. Accordingly, the gear ratios are smaller in order to allow the user to set fast. Such systems have a very low depth of less than 10mm. Additionally, weight is low. Figure 3.4 shows such a system of a Ford 500 (model 2006).

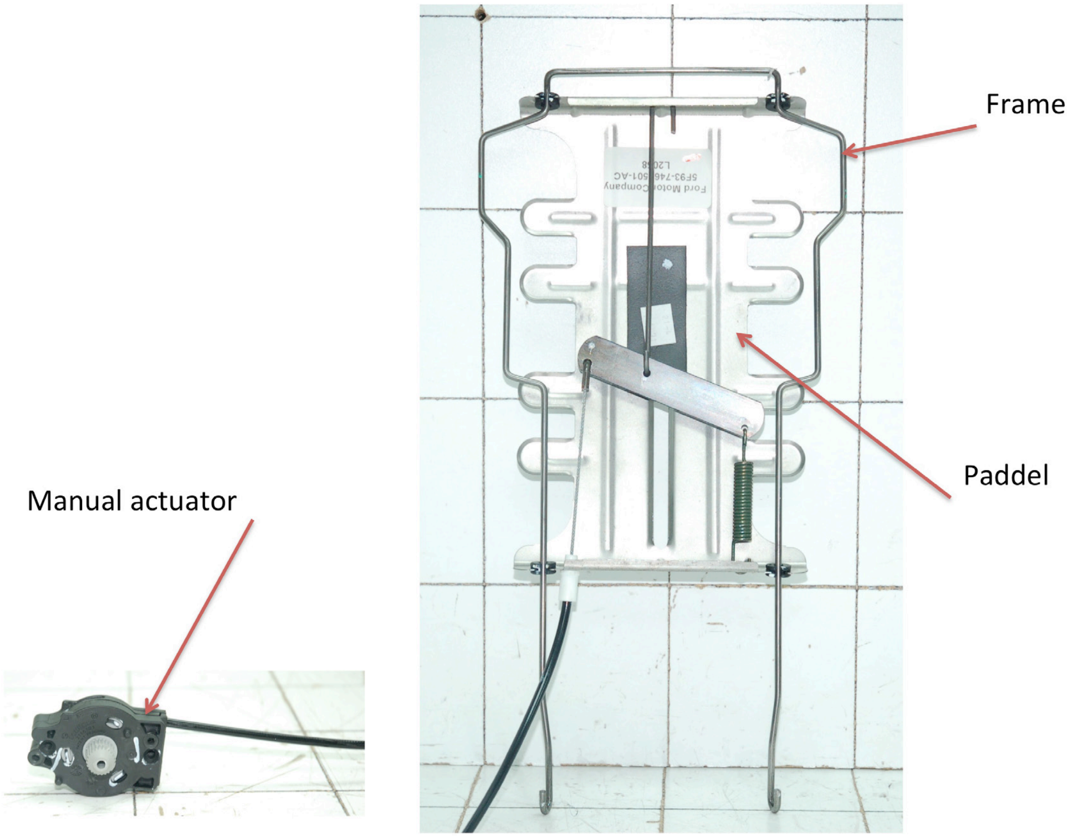

Figure 3.4: Manual system of a Ford 500 model 2006 (referring to an internal source of Magna)

3.2 Cooperation potential

3.2.1 Smarter Alloys

Smarter Alloys processes standard SMA and change their classical one-way behaviour into multi-way behaviour. The company ensures that the material withstands a cycle number of between hundreds of thousands up to a million when used properly. Smarter Alloys applies their Multi-Memory-Material technology on commercially available SMA that are readily available for automotive applications. An expert from the company stated that the price, depending on the complexity and the mass of the product, is typically only a fraction of alternate systems (for example replacing an electromagnetic actuator). The new technology of Smarter Alloys makes an incremental control of adjustment devices possible. An expert from the company suggests embedding several different memories. Each of the memories requires a different amount of current for activation. Hence, several adjusting steps will be achieved. The environmental temperature influence can easily be avoided by choosing an operating temperature that is higher than the environmental temperature. This approach represents a promising alternative to the continuous control system (Smarter Alloys Webpage, 19 February 2013; company expert).

3.2.2 Seas Group

The SEAS Group produces Nitinol wires, tubes, sheets and stripes for the automotive, medical, aerospace and defence market. The company sees itself as the global leader of innovation and production in the field of Nitinol alloys and other superelastics. Embedded in the SEAS Group, the Actuator Solutions GMBH is specialised on the development of actuators based on SMA. In an initial discussion, a company expert suggested using a lash mechanism instead of a continuous control system to hold the position in order to keep the energy consumption at a low level. The company seems to be a promising candidate for cooperation, due to the location of Actuator Solutions in Germany, the willingness to cooperate and the already existing expertise on the field of actuators for the automotive market (Memry Webpage, 19 February 2013; company expert).

3.2.3 Nimesis

Nimesis Technology is a French company with further locations in Luxembourg, Belgium and Germany. The company produces a wide range of materials including Nitinol Nickel-Titanium-Copper and Nickel-Titanium-Iron. As well as Nitinol, Nickel-Titanium-Copper could be used for adjustment devices because it is cheaper than Nitinol and has similar characteristics. After a validation of prototypes, the company ensures a mass production of the customised product. A Nitinol wire with a diameter of 0.38mm and a start temperature of 83 degrees costs, for example, 1,52 Euros per meter, not considering price reduction due to mass orders. Nimesis Technology has production resources to manufacture small, medium or large series, whether it's springs, wires, components in strip shape, or more massive devices. The company develops prototypes according to the customer expectations, keeping in mind the future production to ensure a high productivity of series production (Nimesis Webpage, 19 February 2013).

3.3 Competitors

All considerations regarding the competitors refer to a lumbar support adjustment system. A description of possible competitors for MASA in general is not possible.

3.3.1 The toughest competitors

Faurecia

Faurecia has a weight reduction program to reduce weight of seats targeted, since it accounts for up to six to ten per cent of the total weight of a car. Furthermore, Faurecia sees seat adjustment systems as a core competence. The vision for the future is a “Smart Adjustment” system that adopts not only to the occupant but also to the street conditions (Faurecia Webpage, 22 February 2013). Faurecia produces lumbar support systems for Magna Seating and is therefore either a competitor or, in the case of a license sale, a promising customer.

Legget & Platt

Leggett & Platt developed an Integrated Total Comfort Module. It provides a high level of comfort, outstanding adjustability, lower costs and lower weight. The company has several sub groups like Schukra and the Legget & Platt Automotive Group that focus on the development of sophisticated lumbar support adjustment systems (Legget & Platt Webpage, 22 February 2013).

3.3.2 Potential future competitor

Hyunday Dymos has, according to its own statements, the biggest research centre worldwide regarding automotive seats. The company does research on all essential parts of a seat. Thus, lumbar support adjustment systems and massage functions are part of research program. An additional goal is to set up new production facilities in Europe (Hyunday Dymos Webpage, 22 February 2013).

3.3.3 Market share of competitors

A market share cannot be displayed, since it is a new technology.

3.4 Marketing strategy

3.4.1 Aimed market share

The aimed market share depends on the future decisions of the management concerning the patent application and the decision of which products will be equipped with MASA in the future. Based on a lumbar support adjustment system, at best a market share of 100 per cent can be achieved if the application is patented for all relevant regional markets. However, a market share of 100 per cent is not to be expected, since it is unlikely that due to the extremely high number of different car types and requirement profiles for lumbar support adjustment systems, MASA presents the best possible solution for each of these car types.

3.4.2 Product differentiation

The product differs substantially from competitor products through the unique combination of weight, size and noise reduction. Thus, MASA has a higher benefit value compared to the competitor products and a higher target price can be stated.

4 Risks

4.1 Analysis of the risks

As part of the feasibility study, a SWOT analysis was conducted to identify internal and external risks.

4.1.1 Internal risks

- Difficult controlling
- Restricted adjustment range
- Number of possible adjustment cycles
- Adjustment resets automatically when no energy supply
- The produced heat affects the comfort of the end-user
- Fulfilment of the technical expectations of the OEM's

10.1.1 External risks

- Competitors create the same or even more benefits with other technologies
- Competitors try to apply the same technology
- The suppliers cannot fulfil the technical expectations
- The protection with a patent could be problematic
- Other competitors will reduces the market possibilities

4.2 Countermeasures

4.2.1 Impact of the risks in the worst case - ranking of risks according to the impact on viability

1. Other competitors will reduces the market possibilities

2. Adjustment resets automatically when no energy supply

3. Difficult controlling

4. The produced heat affects the comfort of the end-user

5. Competitors try to apply the same technology

4.2.2 Risk minimisation

1. Other competitors will reduce the market possibilities: It is important to convince the OEMs of the significant advantages the technology has. This can be achieved by pointing out that the combination of noise reduction, weight reduction, cost reduction, and space saving is just achieved with this technology. Furthermore, to convince OEMs of the future potential of the technology in respect to the versatility.

Foster a fast development of the technology to avoid other competitors being faster. As a second step, strengthen the relations with the customers to make a market entry for followers more difficult.

Find new applications for car seats, cars or other areas where an adjustment system with small adjustment range is needed in order to reap the full benefits and to lower the risk of ousting from the market. Use the technology for instance also for middle-class cars to enlarge the market.

2. Adjustment resets automatically when no energy supply: Use a system with a latch mechanism. In this case, electricity is just needed at the time of adjustment and the consumption is significantly lower.

3. Difficult controlling: Incorporate SMA suppliers in an early stage of the project in order to create a sound solution.

Try to use the multi-way technology of Smarter Alloys to realise an incremental control system.

4. The heat produced affects the comfort of the user: Test the prototype in an early stage of the project in order to find out whether the heat causes problems or not. If the heat affects the comfort try to insulate the wire.

5. Competitors try to apply the same technology: Fast patent registration to secure the rights for the technology. Conduct a thorough patent enquiry to make sure that the technology can still be registered as a patent. Keep an eye on the competitors.

5 Revenue potential and financing

A list of earnings and financing potential for MASA is generally not possible at this time. Thus, the following comments are based on a lumbar support adjustment system.

5.1 Projected revenue of the coming years

The projected revenue is based on the assumption that the idea will be used for a license sale, since Magna produces no lumbar support adjustment systems. However, should the management decide to produce in-house the assumptions have to revised taking into account the production and the product costs.

The expected earnings situation is illustrated in Figure 5.1 where the income from the license sale is compared with the investments in regard to time and scenario depended sales figures derived from the market analysis.

5.1.1 Scenario 1: Best case

Scenario A (optimistic case): The potential of the entry market can be exploited due to the fast progression of the project and the high acceptance of the OEMs and end-users. All mentioned OEMs show interest in the technology and implement it in most vehicles of classes E and F in 2014 and 2015. After the successful launch show, almost all the other above-mentioned potential customers show interest so that by 2015, 80% of the entry market and in 2017, 80% of the total market potential is exploited. The development costs are, as estimated, 200.000 Euros. Also the patent fees are, as expected, about 43.000 Euros. The licence fee of the product can be set at 1.5% of the product price. For each car, two lumbar support adjustment systems are integrated, one for the driver and one for the passenger seat in the front. The average product price of state of the art systems is about 12 Euros. Therefore, the licence sale of the new system makes 18 Cents.

5.1.2 Scenario 2: Trend scenario

Scenario B (trend scenario): The potential of the entry market can be exploited due to the fast progression of the project and the high acceptance of the OEMs and end-users. However, little delays due to problems with the technological implementation lead to higher development costs (250.000 Euros). Since the competitors exert pressure, not all named OEMs can be convinced to use the new product for their cars so that, by 2015, 40% of the entry market and by 2017, 40% of the total market potential is exploited. The license fees are set with 1% of the product price, which corresponds to an average level of license fees in this field. The income per car would be 12 Cents.

5.1.3 Scenario 3: Worst case

Scenario C (worst case scenario): The market potential of the entry market cannot be exploited at all due to insufficient technical implementation and the low acceptance level of the OEMs and end-users, even after higher investments than planned. The development costs are, at 300.000 Euros, much higher than expected. The technological problems can only be solved by means of high investments. Additionally, a competitor already launched a similar product so that the management decides to suspend the project and the idea cannot be exploited.

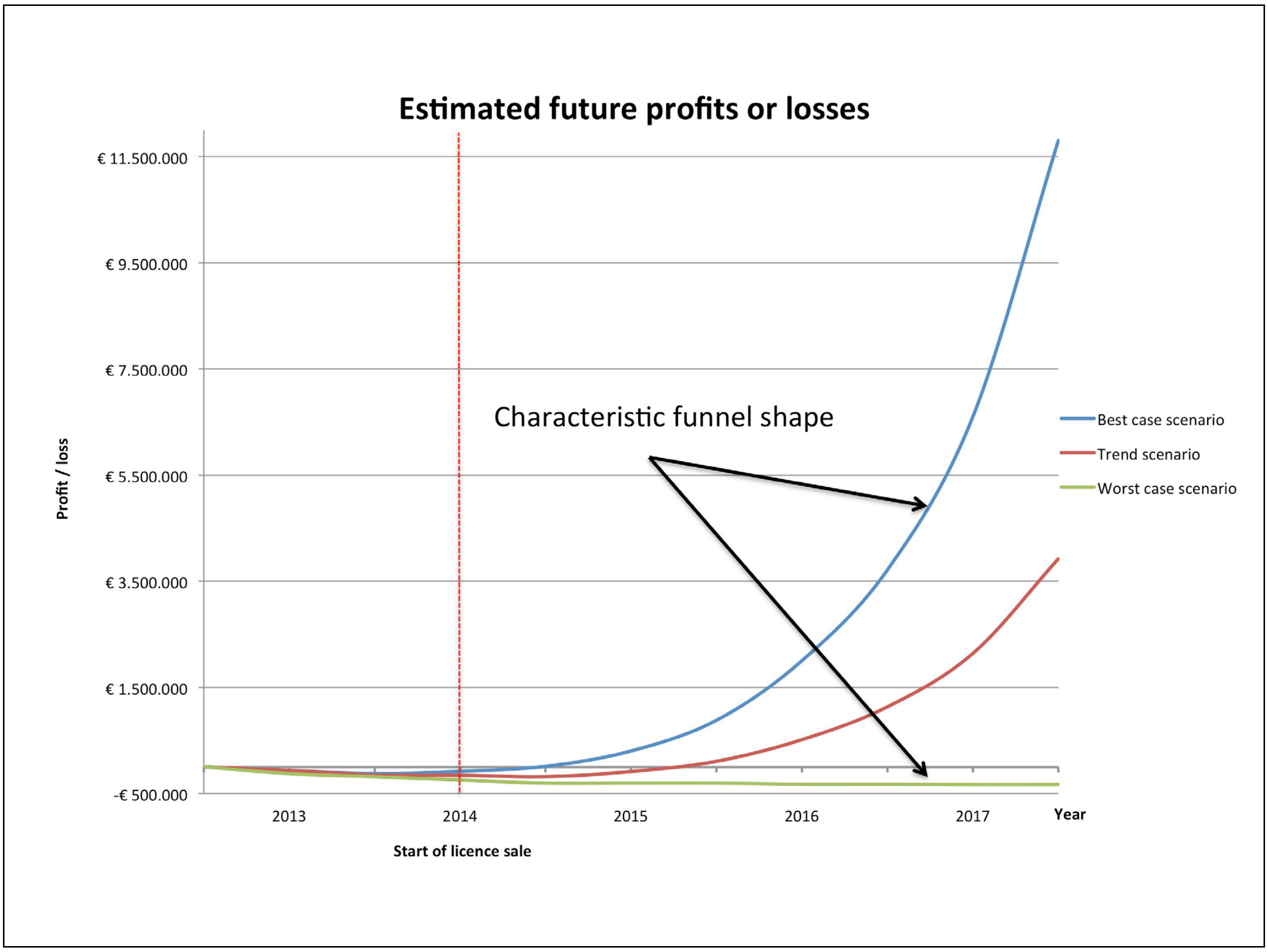

Figure 5.1: Estimation of future profits or losses (own illustration)

5.2 Investments

All following considerations are based on the assumption that Magna will exploit the idea by licence sales. The cost evaluation includes therefore the development costs and patent costs but no costs for the installation and development of production systems or any other costs that are related to a ramp up of an in-house production.

5.2.1 Development costs

The development costs for a lumbar support adjustment system are made up of expenses for the project management, the computer aided design, development of the control system, prototype tests, prototype parts and pre-serial tests. The prototype testing includes tests for durability, heat dissipation and functional stability. The pre-serial tests aim to examine the functional stability in detail and include environmental aspects (climate test, fatigue test, heating-cooling test, tropic test, temperature change test, heat exchange test, pulsator test and endurance test). The total costs were estimated by an expert and amount to approximately 200 000 Euros. Figure 5.2 shows an overview of the cost situation related to the development. Safety tests were not assessed because they differ from country to country and are usually the task of the supplier. Thus, the company, which produces and sells the product, has to carry out such safety testing.

Development costs of a lumbar support adjustment system using the MASA technology

			Costs
Project management			€ 25.000
CAD design costs			€ 20.000
Electronic-control tests			€ 50.000
Prototype parts			€ 25.000
Prototype tests	Durability tests		€ 30.000
	Heat dissipation tests		
	Safety tests		
	Functional stability	- Pulsator test - Endurance test	
Pre-serial tests	Environment tests	- Climate test - Fatigue test - Heating-cooling test - Tropic test - Temperature change test - Heat exchange test	€ 50.000
	Functional stability	- Pulsator test - Endurance test	
		Total costs	€ 200.000

Figure 5.2: Development costs for a lumbar support adjustment system with MASA technology (own illustration)

5.2.2 Patent costs

Patent costs can vary slightly, depending on the application strategy. After consultation with an expert, a European patent application with the extension to the United States, Canada (North America) and China seems to be reasonable. Figure 5.3 shows the composition of patent costs.

Patent costs per year and region

<table>
<tr><th>Year</th><th>Europe</th><th>China</th><th>US, Canada</th></tr>
<tr><td>2013</td><td rowspan="3">€ 4.000</td><td rowspan="4">€ 5.000</td><td rowspan="4">€ 10.000</td></tr>
<tr><td>2014</td></tr>
<tr><td>2015</td></tr>
<tr><td>2016</td><td>€ 7.000</td></tr>
<tr><td>2017</td><td>€ 700</td><td>€ 2.500</td><td>€ 2.600</td></tr>
<tr><td>2018</td><td>€ 700</td><td>€ 2.500</td><td>€ 2.600</td></tr>
<tr><td>2019</td><td>€ 700</td><td>€ 2.500</td><td>€ 2.600</td></tr>
<tr><td>Total</td><td>€ 13.100</td><td>€ 12.500</td><td>€ 17.800</td></tr>
<tr><td></td><td></td><td>Total costs:</td><td>€ 43.400</td></tr>
</table>

= cumulated costs from 2013 until 2016 (costs until granting of the patent)
= cumulated costs from 2013 until 2015 (costs until granting of the patent)

Figure 5.3: Patent costs (own illustration)

5.3 Source of funds

For MASA in general it is difficult to make statements about the source of funds, as the fields of application differ greatly. Therefore, it makes sense that for each application, development costs are borne by each Magna Group, for which the innovation is intended. However, an inter-group cost allocation can take place for certain items, such as the control unit.

Regarding the lumbar support adjustment system, Magna Seating will exploit the technology. Using Magna Seating as a funding source should therefore be suggested. Additional support from OEMs or suppliers is conceivable

Szenario A	2012/1	2012/2	2013/1	2013/2	2014/1	2014/2	2015/1	2015/2	2016/1	2016/2	2017/1	2017/2
Markteintrittspotential	0	0	0	0	4.019.836	4.019.836	4.019.836	4.019.836	4.019.836	4.019.836	4.019.836	4.019.836
Gesamtpotential abzüglich Markteintritsspotential	0	0	0	0	27.733.170	27.733.170	29.808.314	29.808.314	31.440.640	31.440.640	32.119.572	32.119.572
Markterschließung Eintritt %	0	0	0	0	10	20	40	80	80	80	80	80
Markterschließung Gesamt %	0	0	0	0	0	0	0	0	10	20	40	80
Absatz Eintritt	0	0	0	0	401.984	803.967	1.607.934	3.215.869	3.215.869	3.215.869	3.215.869	3.215.869
Absatz Gesamt - Eintritt	0	0	0	0	0	0	0	0	3.144.064	6.288.128	12.847.829	25.695.658
Absatz Gesamt	0	0	0	0	401.984	803.967	1.607.934	3.215.869	6.359.933	9.503.997	16.063.698	28.911.526
Produktreis	0	0	0	0	12,00	12,00	12,00	12,00	12,00	12,00	12,00	12,00
Lizenzgebühr	0	0	0	0	1,50	1,50	1,50	1,50	1,50	1,50	1,50	1,50
Einnahmen	0	0	0	0	72.357	144.714	289.428	578.856	1.144.788	1.710.719	2.891.466	5.204.075
Patenkosten	0	0	4000						22000		5800	
Investitionskosten	0		60000	60000	30000	50000	0	0	0	0	0	0
Ertrag	0	0	-64.000	-60.000	42.357	94.714	289.428	578.856	1.122.788	1.710.719	2.885.666	5.204.075
Ertrag kummuliert	0	0	-64.000	-124.000	-81.643	13.071	302.499	881.356	2.004.144	3.714.863	6.600.529	11.804.603

	bezogen auf Markteintrittspotential
	bezogen auf Gesamtpotential

Gesamtpotential	17886421	17886421	18923993	18923993	19740156	19740156	20079622	20079622

Szenario B	2012/1	2012/2	2013/1	2013/2	2014/1	2014/2	2015/1	2015/2	2016/1	2016/2	2017/1	2017/2
Markteintrittspotential	0	0	0	0	4.019.836	4.019.836	4.019.836	4.019.836	4.019.836	4.019.836	4.019.836	4.019.836
Gesamtpotential abzüglich Markteintritsspotential	0	0	0	0	27.733.170	27.733.170	29.808.314	29.808.314	31.440.640	31.440.640	32.119.572	32.119.572
Markterschließung Eintritt %	0	0	0	0	5	10	20	40	50	50	50	50
Markterschließung Gesamt %	0	0	0	0	0	0	0	0	5	10	20	40
Absatz Eintritt	0	0	0	0	200.992	401.984	803.967	1.607.934	2.009.918	2.009.918	2.009.918	2.009.918
Absatz Gesamt - Eintritt	0	0	0	0	0	0	0	0	1.572.032	3.144.064	6.423.914	12.847.829
Absatz Gesamt	0	0	0	0	200.992	401.984	803.967	1.607.934	3.581.950	5.153.982	8.433.832	14.857.747
Produktpreis	0	0	0	0	12,00	12,00	12,00	12,00	12,00	12,00	12,00	12,00
Lizenzgebühr %					1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
Einnahmen	0	0	0	0	24.119	48.238	96.476	192.952	429.834	618.478	1.012.060	1.782.930
Patenkosten	0	0	4000						22000		5800	
Investitionskosten	0		60000	85000	30000	75000	0	0	0	0	0	0
Ertrag	0	0	-64.000	-85.000	-5.881	-26.762	96.476	192.952	407.834	618.478	1.006.260	1.782.930
Ertrag kummuliert	0	0	-64.000	-149.000	-154.881	-181.643	-85.167	107.785	515.619	1.134.097	2.140.357	3.923.287

(dark grey)	bezogen auf Markteintrittspotential
(light blue)	bezogen auf Gesamtpotential

Gesamtpotential	17886421	17886421	18923993	18923993	19740156	19740156	20079622	20079622

Szenario C	2012/1	2012/2	2013/1	2013/2	2014/1	2014/2	2015/1	2015/2	2016/1	2016/2	2017/1	2017/2
Markteintrittspotential	0	0	0	0	4.019.836	4.019.836	4.019.836	4.019.836	4.019.836	4.019.836	4.019.836	4.019.836
Gesamtpotential abzüglich Markteintritsspotential	0	0	0	0	27.733.170	27.733.170	29.808.314	29.808.314	31.440.640	31.440.640	32.119.572	32.119.572
Markterschließung Eintritt %	0	0	0	0	0	0	0	0	0	0	0	0
Markterschließung Gesamt %	0	0	0	0	0	0	0	0	0	0	0	0
Absatz Eintritt	0	0	0	0	0	0	0	0	0	0	0	0
Absatz Gesamt - Eintritt	0	0	0	0	0	0	0	0	0	0	0	0
Absatz Gesamt	0	0	0	0	0	0	0	0	0	0	0	0
Produkt Preis	0	0	0	0	12,00	12,00	12,00	12,00	12,00	12,00	12,00	12,00
Lizenzgebühr	0	0	0	0	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01
Einnahmen	0	0	0	0	0	0	0	0	0	0	0	0
Patenkosten	0	0	4000						22000		5800	
Investitionskosten	0		120000	60000	60000	60000	0	0	0	0	0	0
Ertrag	0	0	-124.000	-60.000	-60.000	-60.000	0	0	-22.000	0	-5.800	0
Ertrag kummuliert	0	0	-124.000	-184.000	-244.000	-304.000	-304.000	-304.000	-326.000	-326.000	-331.800	-331.800

(dunkelgrau)	bezogen auf Markteintrittspotential
(hellblau)	bezogen auf Gesamtpotential

Gesamtpotential	17886421	17886421	18923993	18923993	19740156	19740156	20079622	20079622