FUTURE SCENARIOS
FOR THE DERIVATION OF MATERIAL REQUIREMENTS
– THE AUTOMOBILE INTERIOR 2030

A thesis submitted by

Elena Nicole Weccard

to

University of Twente,
Technische Universität Berlin,
and the Daimler AG

in part completion of the requirements for the

Double degree
M.Sc. Business Administration
and M.Sc. Innovation Management and Entrepreneurship

- Public Version -

Daimler AG:
Department:
Supervisor:

University of Twente, School of Management and Governance,
NIKOS - Netherlands Institute for Knowledge Intensive Entrepreneurship:
Dr. Kasia Zalewska-Kurek
MBA Raymond Loohuis

Technische Universität Berlin, Chair of Innovation Economics:
Dipl.-Math. oec. Kerstin Goluchowicz
Prof. Dr. Knut Blind

December 10, 2012

ABSTRACT

The automotive industry experiences an enormous change. Tightening CO_2 regulations, a shift of the industry's gravity center, resource scarcity and the emerging phenomenon of car sharing are just some of the developments that result in an uncertain environment. An important topic that has not been addressed yet and that will be strongly influenced by these developments is the future interior of the automobile and the requirements that will be opposed to the material embedded in it. Investing in the research for future materials for the interior contains high level of risks because the researchers are missing the crystal ball that would tell which are the most relevant issues to research. Therefore recognizes the Daimler AG, a German multinational automotive cooperation, the need to closely examine social, technological, ecological, economic and political factors that influence the development of the automobile interior in order to derive future material requirements and to recommend areas for particular attention and potential investment for new research projects in the field of automotive interior design, which will be addressed by the first central research question:

Central question 1: The development of which material research areas will be crucial during the next 18 years in the automobile interior design?

Currently, the research department "Interior materials, manufacturing and concepts" mainly bases its research strategy on the suggestions of employees and suppliers and has no systematic process to identify material requirements in the long-term. The department would like to apply a process that is particularly useful in a turbulently changing environment and that enables to derive future material requirements in the automobile interior and the identification of materials that fulfill them. Therefore, a second central research question is formulated:

Central question 2: Which scenario method enables a derivation of future material requirements in the automobile interior and the identification of materials that fulfill those requirements?

The first central research question has three subquestions that must be answered before the central question can be addressed:

Subquestion 1: Which key factors in the environment have an impact on the automobile interior design of the future and which possible developments of these factors are expected till 2030?

Subquestion 2: What are internally consistent, plausible, and challenging alternative scenarios of the automobile interior environment 2030?

Subquestion 3: Which future requirements for the material applied in the automobile interior can be derived from the scenarios?

Due to confidentiality the rest of the abstract has been excluded.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

B2C	Business-to-consumer
BRIC	Grouping acronym that refers to the countries of Brazil, Russia, India and China
CH_4	Methane
COPD	Chronic obstructive pulmonary disease
DBL	Daimler Benz Liefervorschrift (Daimler Benz delivery specification)
DILO scenarios	"Day in the life of" scenarios
FC	Fluorocarbon
Fig.	Figure
GDP	Gross domestic product
GEO	Global Ecosystem Organization
HFC	Hydrofluorocarbon
ICE	Internal combustion engine
IPR	Intellectual property right
LED	Light-emitting diode
N_2O	Nitrous oxide
N11	Next eleven (eleven countries - Bangladesh, Egypt, Indonesia, Iran, Mexico, Nigeria, Pakistan, Philippines, Turkey, South Korea and Vietnam)
NFP	Not for profit
OEM	Original equipment manufacturer
PA	Polyamide
PC	Polycarbonate
PCM	Phase change material
PES	Polyester
PEST analysis	Political, economic, social and technological analysis
P2P	Peer-to-peer
PP	Polypropylene

PP/GF	Polypropylene with glass fiber reinforcement
PP/NF	Polypropylene with natural fiber reinforcement
PET	Polyethylene terephthalate
PUR	Polyurethane
PVC	Polyvinyl chloride
R&D	Research and development
SF	Sulfur hexafluoride
SIM	Subscriber identity module
STEEP analysis	Social, technological, ecological, economic and political analysis
V2V	Vehicle-to-vehicle
V2X	Vehicle-to-infrastructure
VOC	Volatile organic compounds

1 INTRODUCTION

“Anyone can learn from the past.
These days it is more essential to learn from the future.”
Herman Kahn (1922–1983) was a military strategist, cyberneticist, and a superstar of futurology. He became famous for his theories on the Cold War.

Organizations are confronted with major challenges in an increasingly dynamic and complex environment. Especially the automotive industry experiences an enormous change (Weiss, 2011). Resource scarcity, rigorous environmental specifications, a reorientation to emission-free mobility and a shift to the BRIC countries as most important markets are just a few of the factors that result in a turbulent and uncertain environment (von der Gracht & Darkow, 2010). The automotive industry will be confronted with major challenges but will also afford opportunities. The potential impact of these factors calls for an analysis of future requirements to foster innovations in order to stay competitive and develop the ability to adapt quickly to changes (Halldórsson & Kovács, 2010; von der Gracht & Darkow, 2010).

The rising awareness to the future of the automobile becomes apparent in the various trend studies developed concerning this topic. Most of the studies focus on the drift to emission-free mobility or the relocation of production facilities. An important topic that has not been addressed yet is the interior of the automobile with its changing requirements. After decades of little change in car interiors, the next years are likely to revolutionize the driving environment (Blackburn, 2009). New design opportunities due to alternative propulsion systems, the conquest of automobiles by driver assistance systems, as well as the development of innovative mobility concepts have an impact on the interior design and will change the requirements concerning the inside of an automobile. Their identification will support research and development (R&D) executives in deriving long-term strategies. So in the next few years, we may well see the future of the motor car being significantly influenced by factors which have nothing to do with traditional automobile technology. Openness to new ideas will be the key to securing our future mobility (Kaiser, Eickenbusch, Grimm, & Zweck, 2008).

A study by the National Academy of Science and Engineering showed that 70 percent of all new products are based on new materials, considered to be the force driving innovations (Acatech & Fraunhofer IRB, 2008). Materials innovations also play a very important part in modern vehicle construction (Pannkoke & Seitz, 2010). The above mentioned developments press for great progress in different aspects of materials.

The Daimler AG, a German multinational automotive cooperation, recognizes the need to closely examine the field of materials that might fulfill the future requirements of an automobile interior in 2030 to recommend areas for particular attention and potential investment for new research projects in the field of automotive interior design.

1.1 BACKGROUND

Investing in the research for future materials for the interior contains high level of risks because the researchers are missing the crystal ball that would tell which are the most relevant issues to research. The fact remains that the future is unpredictable. Nevertheless, some developments can be foreseen and alternatives can be thought of. Therefore, there is the possibility of preparing for the future or to try to shape it actively (Cuhls, 2003). Scenarios are not concerned with getting the future "right", but rather picture several alternative futures (Wulf, Meißner, & Stubner, 2010; Bishop, Hines, & Collins, 2007). In this way, scenarios prepare planners to be better able to recognize changes, to make decisions today, and adapt to changes tomorrow (Wilkinson, 1995; Zegras, Sussman, & Conklin, 2004).

In requirements engineering scenarios are applied differently. They determine requirements of a user or system and are used as a tool to identify and communicate requirements because they help people to think past the obvious, to detect the real requirements and to come up with innovative ideas. Scenarios can be seen as a vehicle for involving people in telling stories by exploring a scene and in doing so realizing the requirements and thus reduce the complexity of systems and analysis (Robertson, 2004). The final availability of a complete set of requirements is a pre-requisite for designing a system (Sutcliffe, 2003). However, the approach is used to depict the current requirements of users and systems yet it does not deal with possible future requirements.

With time customer needs and system requirements change but the requirements of the future are hard to predict. Therefore, a combination of the two application areas can be used to determine system requirements in a future environment.

1.2 RESEARCH GOAL

This study uses scenarios both as a strategic planning tool for alternative futures and as a requirements analysis tool. A scenario analysis is performed to address the uncertainty in the automotive industry by identifying factors that influence the automobile interior design up to the year 2030. Based on this analysis future material requirements are derived and the currently applied material is tested in order to identify areas in the requirements that cannot be fulfilled by them. Goal is the discovery of new material research areas or the validation of existing ones at the Daimler AG that prepare for different potential developments in the environment of the automotive industry. This contributes to the capacity of the company to handle uncertainty and to adapt rapidly to changes and is a key factor for success (Varum & Melo, 2010). Automakers will need to reinvent themselves to meet the challenges of a dramatically new global automotive landscape (Deloitte, 2009a), which means that strategically well-aimed research effort may lead to a competitive advantage. Furthermore is the key stakeholder, the research department “Interior materials,manufacturing and concepts” at the Daimler AG, introduced to scenarios as a multi-sided tool and is able to broaden its view of the future with alternative horizons.

The research makes five important contributions to the existing body of literature. First, the revolution of the driving environment is addressed and especially factors discovered that change the interior of the automobile. Second, the study gives an overview of future material requirements that have to be taken into account in the future. Third, the study extends the scope of application of scenario planning to the context of material. Fourth, a tailored 7-step scenario based process that was designed to specifically draw requirements from future environments via scenario and requirements analysis is presented. This thesis delineates itself by providing detailed advice about how scenarios can be used in future requirements elicitation and testing. Fifth, it is demonstrated how scenarios can be utilized in an early phase of innovation in order to paint a consistent picture of the future and provide new inspiration for research projects.

1.3 RESEARCH OBJECTIVES

To make the problem more convenient to handle, a handful of objectives is recognized and achieved during the research.

The spanning objective is the identification of new strategic research areas at the Daimler AG. However, to reach this objective some sub-ordinate targets have to be accomplished. First, the influencing factors of the future automobile interior evolution have to be identified. Second, a determination of the key factors is required. Third, the future projections concerning the key factors to expose the “area of possibility” have to be developed. Fourth, several consistent scenarios presenting alternative futures are needed. Fifth, future requirements for the material in the interior have to be identified by expert consultation and tested in the light of currently applied material. Additionally, an example solution that fulfills some of the requirements has to be found.

1.4 RESEARCH QUESTIONS

To conform to the requirements of the research goal, the research focuses on the identification of relevant areas of strategic research concerning material characteristics needed in the automobile interior in the year 2030. Therefore, the first central research question is:

Central question 1: The development of which material research areas will be crucial during the next 18 years in the automobile interior design?

(Due to confidentiality this part of the thesis has been excluded.)

In order to be able to derive future material requirements and to find solutions for the identified requirements, a second central research question is formulated:

Central question 2: Which scenario method enables a derivation of future material requirements in the automobile interior and the identification of materials that fulfill those requirements?

The first central research question has three subquestions with the intention to achieve the spanning research objective and identify new strategic research areas. Due to the size and complexity of the automotive industry environment and its effect on the automobile interior directing expensive research to the "right" targets is difficult. Thus, desire for understanding and bounding the uncertainties relating to the future development of the materials required increases. This thesis eases the problem through scenarios which disclose the most significant influencing factors. The supporting research questions to Central Question 1 are expressed as follows:

Subquestion 1: Which key factors in the environment have an impact on the automobile interior design of the future and which possible developments of these factors are expected till 2030?

Subquestion 2: What are internally consistent, plausible, and challenging alternative scenarios of the automobile interior environment 2030?

All systems change over their lifetimes, so that they robustly fulfill their requirements in the face of the changes they are confronted with. An alternative application possibility of scenarios is the detection of requirements (Alexander & Maiden, 2004). This leads to another supporting research question:

Subquestion 3: Which future requirements for the material applied in the automobile interior can be derived from the scenarios?

The identified requirements are then the basis for the identification of one example solution outside the automotive industry that can fulfill several of the future requirements. For the example the house construction industry was chosen. The materials applied in house construction in Germany have significantly changed in the last couple of years due to stricter environmental regulations (e.g. the Energy Conservation Act, Bundesministerium der Justiz, 2009) and new customer requirements concerning style and the costs of houses. The material change in this industry is quoted as the *"material revolution"* (Peters, 2011, p. 11).

It is intended to mainly derive a material strategy, but as it is presumed that in the future technology will be intensively integrated in material and has a high influence on production (Antón, Silberglitt, & Schneider, 2001) technologies are in the strategy not negligible and therefore included.

The resulting scenarios are approaches that display possible developments (Wright & Cairns, 2011). Displaying those alternative development trajectories serves as stimulation to the actors involved in the R&D process. By means of the results in comparison to the current material applications, existing gaps in the research strategy can be closed or the intensification and further development of areas (for future changes in the environment) can be prepared.

1.5 METHODOLOGICAL ATTEMPT TO APPROACH THE TOPIC

For the development of this thesis a comprehensive methodological concept was required to open access to this complex and extensive matter. Chapter 2 is based exclusively on literature research. To analyze the data the hermeneutic method was used, with the main purpose to evaluate, to understand and to interpret the collected data in a broader context as part of the whole. In the scope of this method the collected data should be connected with previous and contextual knowledge to build a knowledge basis for the study and to draw appropriate conclusions in terms of the research questions (Patzelt, 2003). The study is based on expert interviews to enrich the scenario process since they help to achieve a common consensus as well as challenge assumptions. The systematic-formalized scenario method utilizing mathematical algorithms, described in more detail in the third chapter, for the development of explorative scenarios consists of the four steps of an ideal-typically scenario process. Data collection methods to gather influencing factors included a literature research and a STEEP analysis with brainstorming. A patent analysis was conducted to confirm technological trends. The most important influencing factors were identified during a workshop and by means of expert interviews that were then the basis for an influence analysis. Projections were developed with a further literature research and a small qualitative patent analysis. The decision which scenario bundles to choose for the following requirements analysis was also made with a workshop that formed the basis for a consistency and cluster analysis. Data for the requirements analysis was collected with expert interviews and analyzed with qualitative content analysis to derive strategic material research areas. Building on these results other industries were scanned with a literature research to find a new material solution applicable to the automobile interior in the future.

1.6 RESTRICTIONS ON THE SCOPE OF TERMS

In particular the term 'scenario' requires further explanation as there appears to be virtually no area on which there is wide-spread consensus (Bradfield, Wright, Burt, Cairns, & van der Heijden, 2005). The literature exposes a huge number of differing definitions, characteristics, principles and methodologies about scenarios (Mason, 1994). Simpson states that the term evokes all sorts of 'vague and loosely defined concepts' (Simpson, 1992, p. 2). The consequence is that hardly any techniques in futures studies have led to so much confusion as scenarios (Khakee, 1991). A dictionary definition holds it as "an outline of a natural or expected course of events", a broad definition that includes both scenarios in future planning and requirements analysis (Random House Webster's college dictionary, 1999).

In the field of future studies it gained a more specialized connotation:

There are varying definitions of 'scenario' but on one point there is consensus: *"it is not a prediction"* (Wack, 1985, p. 143; van der Heijden, 2002, p. 53). Characteristics inherent in the various definitions include that a scenario is: hypothetical, causally coherent, internally consistent, and/or descriptive. A definition which covers many of the characteristics proposed by others and used in the course of this thesis is:

> an *"internally consistent, plausible, and challenging narrative description […] of possible situations in the future, based on a complex network of influencing factors* (Gausemeier, Fink, & Schlake, 1998, p. 114; van der Heijden, 2009, p. 114; von der Gracht & Darkow, 2010, p. 47), *which can serve as a basis for action"* (van Notten, 2005, p. 2).

Over time, a variety of terms like planning (Potter & Roy R., 2000), technique (Geschka & Hammer, 1983), analysis (Mißler-Behr, 1993), development (Shoemaker, 1993) and building (de Jouvenel, 2000) are generally attached to the word scenario (Bradfield et al., 2005; Varum & Melo, 2010). In this thesis, it is subscribed to the delineation by Martelli (2001) and Bishop et al. (2007) who argue that scenario development, building and analysis are seen as the method to work out and formulate the scenarios, whereas scenario planning is an umbrella term that also includes the decision-making or strategy derivation based on the scenarios. Scenario technique is sometimes used as a term to describe a special method of scenario development, in which the scenarios are built as a systematic combination of alternative projections of a set of key factors (Fink, Schlake, & Siebe, 2002; Gausemeier, 2009; Richter, 2010) - the method which is used in this study. However, the literature mostly makes no distinction between method and technique thus the terms will also be used interchangeably.

Systems are *"complex structures made up of interacting components, […] with many possible interaction sequences for any system"* (Alexander, 2004, p. 13). In requirements engineering the term "system" is mostly used interchangeable with the product or software that is developed.

However, sometimes only a specific part of the product is meant that is taken into consideration. This study concentrates on the interior of the automobile. The interior design describes *'a group of various yet related projects that involve turning an interior space into an effective setting for the range of human activities that are to take place there'* (Pile, 2003, p. 12). Given that the key stakeholder is an automobile manufacturer, the project concerns the interior of a passenger car.

A requirement is a *'statement that a system is to satisfy, whether*

a) by providing a desired functional result […]

b) by having a desired quality such as a given measure of performance or reliability

c) satisfying some external constraint such as an interface definition or energy consumption' (Alexander & Maiden, 2004, p. 509).

In the case of this study, it is explicitly focused on the material in the interior to fulfill the imposed requirements.

There is also no generally valid definition and no uniform understanding of the term 'strategy'. Representatives of the classical understanding of strategy, e.g. Chandler (1962, p. 13), comprehend strategy as *"the determination of the basic long-term goals […], and the adoption of courses of action and the allocation of resources necessary for carrying out these goals"* with strategy as the result of formal and rational planning. According to Mintzberg (1994), a representative of the extended understanding of strategy, coincidental strategies do occur, whose realization was not intentional and is often based on short-term decisions of employees and reactions on problems and chances. This paper solely focuses on strategies that are based on formal and rational planning. Strategy is equalized with *"the determination of basic long-term goals"* and strategic research areas are seen as scientific domains, which are considered to be of strategic importance for the R&D department. Gaps are pointed out that should be addressed with further research because the currently applied material is not able to fulfill the requirements opposed to it. Explicit courses of action and the allocation of resources to address the goal are not part of this study.

1.7 CONTENTS OF THE REPORT

The remainder of the thesis is organized as follows: Chapter 2 is the theoretical basis for this study and gives an introduction into the automotive industry and its material requirements in the interior. It furthermore aims at the multifaceted application areas of scenarios and thereby explains why scenarios are an ideal tool for this matter. The chapter leads over to Chapter 3 with the scenario approach that was chosen to develop the future environments – a background that is required in order to understand the "methodological chaos" surrounding the subject of scenario planning and the process consisting of scenario analysis, requirements analysis and scanning in order to answer the research questions. Chapter 4 illustrates the main methodology of this study – expert interviews. It gives information to the selection of experts and the software applied. Chapter 5 is dedicated to the results of the scenario analysis, the requirements analysis and the scanning. In Chapter 6 recommendations are given to the Daimler AG. Chapter 7 contains the summary, the study's contributions to theory and practice, the limitations of the study and suggestions for future research. It finishes with a discussion divided into two parts. The first one concentrates on the applied approach, the second one reflects the study's results.

2 THEORETICAL FRAMEWORK

From the research questions, the theoretical frame can be derived. Mainly two fields are needed and define the theoretical boundaries. The first one is the context of the study – the automotive industry and the material of the automobile interior. The second theoretical field are scenarios and their multi-application possibilities and why these possibilities make them a useful tool in this study. The first two subchapters are dedicated to the reference topic – the automobile. Chapter 2.1 describes current developments in the field and reflects the need for scenario planning in the automotive industry. It is then continued with an overview of the current material requirements for the interior in Chapter 2.2. Chapter 2.3 focuses on scenarios as a strategic foresight tool by displaying alternative futures. As a specific application area R&D planning is addressed. The following chapter concentrates on scenarios as requirements analysis tool. Chapter 2.5 shows how these two application areas can be combined and delineates this study from other research conducted in this area. It is concluded with a summary marking scenarios as multi-sided tool.

2.1 CONDITIONS IN THE AUTOMOTIVE INDUSTY

The automotive industry is of particular interest because the environment used to be quite stable, but will experience a high dynamic in the future. Furthermore, is it a large industry characterized by a high complexity with many interacting influences. Recent research identified several major developments relevant for the automotive industry. For one thing, the growth driver has shifted away from traditional to emerging markets, which has a large impact on product development (Kalmbach, Bernhart, Grosse Kleimann, & Hoffmann, 2011). Simultanuously, societal concerns about energy, congestion, material usage and the environment are drastically changing the attitude towards cars and their usage (Deeg, Görner, Greiner, Petschnig, & Schneider, 2011). An ageing society in industrial countries might have different expectations of their means of transportation (Barthel et al., 2010). The industry is used to produce and sell vehicles but now they have to face the fact that they might sell mobility in the future – a very different proposition. Technological trends add to these uncertainties. The speed with which new technology enhances safety, reduces exhaust emissions and improves overall operating efficiency continues to accelerate. These capabilities may define a car‘s appeal just as much as style and price (Hanley, Henning, Valsan, & Nassif, 2011). The developments require flexibility, creativity and readiness. Therefore, companies in this industry have to adapt their products to the changing environment and demands.

By structuring the analysis of the factors that will change the automobile environment and thus the interior and its materials around the STEEP framework, the following macro areas were taken into account.

Social influences:

The attitude and composition of society can strongly influence the automobile interior. The customers decide how their interior should be designed and which features it should include as they are the ones that buy the product. The development of society may change the function of the car and the way it is used. The dynamics of customer behavior have surprised both the automotive industry and experts. To set a strategic course forward at this juncture, it is necessary to recognize the larger social trends that will have an impact on automotive sales over the long term. This way, manufacturers can properly anticipate their effect on consumer demand and respond with the right products and services for the 2030 automotive customer. The public opinion can form the position of policy-makers that are dependent on their benevolence for their reelection. Major reforms in the automobile sector cannot be implemented against the will of the majority of the population.

Technological influences:

Technology is the practical application of new knowledge in the form of hardware (machines, products, etc.) and software (processes, methods, etc.) to enhance human capabilities for the achievement of targets. They describe tools, instruments or methods with which humans can better or more easily reach their targets. Technological progress enables advances in the material that is used in the interior as well its production. It offers new possibilities in the features included but has also a significant effect on the way automobiles are used, interconnected and steered.

Ecological influences:

Ecological factors are a very broad category that focuses on the global eco organism. The category includes anthropogenic factors that display the consequences of human behavior and counteracting concepts and technologies. Climate change and resource scarcity are factors that can change the attitude of the society, may result in a new method of use of automobiles, require the replacement of certain resources and hence alter the automobile interior.

Economic influences:

Economic influences create new realities inasmuch as they are the framework in regard to which society and organizations develop targets and strategies to address their requirements and needs. Economic changes have an influence on the way of production and the material available. They determine for example the purchasing power and a shift to new markets, which are definitions of the target group of the automobile interior.

Political influences:

Political factors are constitutive interventions of superordinate authorities like the nation states but also nongovernmental organizations and associations in the form of laws, standards, and regulations. Political power reinforces or weakens the realization possibilities of targets. They can for example restrict the variety of material that can be used in the interior or enable through the suspension of security regulations the application of other materials.

It has to be mentioned that not all factors can clearly be assigned to just one category. There are factors in which the influencing areas overlap.

Due to its new role, the automotive industry is an important future market for material developers as they have the opportunity or even the necessity to contribute to the challenges that will emerge from the changes described above. Managing these uncertainties and finding new material solutions for these challenges reflects the need for long-term planning and in particular scenario planning for new requirements.

2.2 MATERIAL IN THE AUTOMOBILE INTERIOR

This subchapter explains the main characteristics that a suitable interior material should currently have to be accepted in automotive production. Some of the selection criteria are the results of regulation and some are the requirements of the customers. In many occasions different factors are conflicting and therefore a successful design is only possible through an optimised and balanced solution (Fuchs, Field, Roth, & Kirchain, 2008). Ghessemieh (2011) gives an overview of the three state of the art requirements that material should fulfill in automotive application: cost, lightweight and safety.

The most important factor concerning materials in the automobile is cost. Since the cost of a new material is always compared to that presently employed in a vehicle, it determines whether any new material has an opportunity to be selected for a vehicle component (Ghassemieh, 2011).

As there is a high emphasis on greenhouse gas reductions and improving fuel efficiency in the transportation sector, all car manufacturers are investing significantly in lightweight materials R&D and commercialization (Taub, 2006). A large number of publications have recently emerged on the subject of lightweight automotive design (Goede, Stehlin, Rafflenbeul, Kopp, & Beeh, 2009). Studies indicate that ten percent mass reduction relates to a three to seven percent benefit in fuel consumption. One example is the trend to replace structural steel parts with aluminum. But weight reduction often comes with a penalty on costs (van der Wiel, 2012). Because the single main obstacle in application of lightweight materials is their high cost, priority is given to activities to reduce costs through development of new materials and manufacturing processes.

To gain a reduction in weight on the one hand and to still be cost efficient on the other hand, plastics are more and more utilized in the automobile interior. Whilst the synthetic fibers are traditionally used, the natural fibers hold a relatively new place with substantial potential for growth due to the growing environmental concerns. However, these fibers can only be applied when they imply cost reductions (Amancio-Filho & dos Santos, 2009).

The ability to be survivable for the passengers is also one of the essential characteristics of material (Ghassemieh, 2011). Specific safety regulations like the ability to absorb impact energy are imposed on the materials that can be used in an automobile.

The materials selection procedure adopted by the major car manufacturers is mainly restricted to these very few requirements stated above. The physical and mechanical properties of a material are of basic engineering importance (Davies, 2012). But it is assumed that the range of material requirements will significantly increase due to new challenges in the automobile industry. The scope of the current selection criteria must be widened to include other factors that result from changes in the global environment. A survey conducted with over 1,000 automotive professionals showed that most of the respondents think that the currently available material portfolio is not able to meet the requirements that will emerge till 2025 (Glasscock, 2011). OEMs are challenged to close the gap between their current production and future material needs. A result that emphasizes the need for this study to find out which requirements will emerge in the future. Therefore one aim of this thesis is to provide an overview of the wider considerations that have to be taken into account regarding the choice of materials beyond just the inherent properties weight, safety and costs as these new criteria should direct R&D efforts.

From a global manufacturer of high-tech interiors point-of-view, it is of great importance for their success to consider all factors that could directly or indirectly affect these requirements. Due to changes in the global environment new demands or regulations arise from the impact of the above mentioned trends.

In contrast to the resource interaction approach that sees resources (in this case materials in the automobile interior) in a complex system with other resources all connected via interfaces and focuses on the processes of resource interaction (Baraldi, Gressetvold, & Harrison, 2012), this study views each resource as uncoupled entity that does not interact with and thereby change the interfaces that it has with other resources. This does also imply that the automobile interior is considered an uncoupled entity that does not interact with e.g. the exterior. The chain reactions in which a change of material, or a change in the vehicle architecture might result concerning the technical and economic, but also social features of the resource, are in this study neglected. The resource interaction approach expands the focus from the single firm to the level of interorganizational networks where the economic value of resources is shaped (Baraldi et al., 2012). Though this study places its central focus on the R&D departments of the Daimler AG and does not take into account that this key stakeholder belongs to a very large network of companies with inter-organizational relationships that might be affected when a change of resources occurs. Hakansson and Waluszewski (2002) argue that it is difficult to change resource combinations because they are historically developed interdependencies across resources embedded in interfaces. However, this study makes these simplifications as the automobile interior consists of many different parts with different materials that might have to be changed or would result in frictions and tradeoffs if modifications are made on one material. The tracking of all the changes in the complex network of automobile parts consisting of various materials would exceed the processing capacity of the participants of the study and the time capacity of the thesis. Furthermore showed previous research projects at the key stakeholder that when resource interactions are considered from the beginning, creativity and motivation is hindered because the researchers have the feeling that the material has such a strong embeddedness that change would not possible – an attitude that diminishes the innovation capacity of a company. With this view the study rather draws upon the resource based view that focuses on firm-bound internal resource combinations, which are the driver of competitive advantage for the single firm controlling these resources (Baraldi et al., 2012).

Futures studies to derive material requirements are a topic that has not been addressed in the literature[1]. It is argued that in order to be able to derive future material requirements from an unknown future environment with an unknown future system, a combination between scenario analysis for alternative futures and requirements analysis is needed.

2.3 SCENARIOS AS STRATEGIC FORESIGHT TOOL FOR ALTERNATIVE FUTURES

Scenario planning has been identified as one of the most suitable approaches for long-range planning (Courtney, Kirkland, & Viguerie, 1997, p. 78; Shoemaker, 2002, p. 47, 48; Phelps, Chan, & Kapsalis, 2001, p. 223-224; Powell, 1992, p. 551). The positive impact of its usage has been confirmed empirically. Over 30 studies have found a positive relationship between long-range planning and corporate performance over the past 50 years (see e.g. Ansoff, Avner, Brandenburg, Partner, & Radosevich, 1970; Miller & Cardinal, 1994; Rhyne, 1986). The main contributions of scenario planning incorporate thinking in alternatives, enhancing a planners' perception, and offering a structure for dealing with uncertainty (van der Heijden, 2009, p. 142-

[1] "Material requirements planning", a frequently used term, has to be delineated from the topic of this study because this concept is a production planning and inventory control system for material.

144; von der Gracht & Darkow, 2010, p. 47). Especially in cases where the future is clouded and complex, scenarios are useful in guiding and simplifying discussions (Haaker & van Buuren, 2005). According to Graf (2000) are scenarios by now the most important method for dealing with the future, or to be more precise, for dealing with multiple futures. This has to be seen critically because scenario planning is not a replacement for other planning techniques. It rather aims to help organizations better prepare for the unexpected (Zegras et al., 2004).

In 2010, Varum and Melo published an extensive bibliometric study on scenario planning publications. One of the main results of their study was that 70% of all scenario planning publications were issued after the year 2000, confirming a considerable increase in research in this field in recent times.

The overview of relevant articles concerning scenario planning for the automotive industry imitates the general trend in scenario planning publications revealed by Varum and Melo as the number of publications has increased for years (Turton, 2006; Ou, Zhang, & Chang, 2010). Especially in mobility, scenario planning focuses on macro-environmental aspects such as infrastructure, environmental issues and policies.

Decision makers face an increasing uncertainty in the business environment today as the frequency with which elements in their environment change and the amount of elements and their interdependencies increases. In order to stay competitive organizations continually have to rethink their concepts and provide new solutions and innovations (Henning, Hees, & Hansen, 2009). This uncertainty can be particularly addressed in scenario planning since a large network of influence factors is woven into an '*internally consistent, plausible, and challenging narrative description'* of the future *(*Gausemeier, Fink, & Schlake, 1998, p. 114; van der Heijden, 2009, p. 114; von der Gracht & Darkow, 2010, p. 47).

Oftentimes, the aim of scenarios is to make a contribution to strategy development in organizations. In the literature there is only little attention paid to the connection between scenario analyses and strategy development as well as the underlying methods. Thus, how to derive strategies by means of scenarios sometimes stays blurry. Strategies have several characteristics: they regard external situations and developments, as well as chances and risks and react on changes in the environment of the organization or try to actively influence them; they define activity fields of the organization and they are future-oriented and based on the expectations about the development of the own competences and the environment (Mietzner & Reger, 2009a). Scenarios are applied to test existing strategies or to develop new ones.

Scenario planning can also support innovation management. However, this area of research has only scarcely been addressed in the literature (von der Gracht & Stillings, 2012). The scenario technique is utilized to inspire and to create a more robust picture of potential market developments, political regulations or customer needs. It serves as a creativity tool that enables the systematic generation of ideas (Drew, 2006; Goetheer, Heijs, & Oelen, 2010).

R&D departments in particular are facing more pressure to change and more uncertainty regarding the path forward (Deloitte, 2009b). Various empirical investigations showed that the rate of change is increasing because product life cycles are shortening (Kessler & Chakrabarti, 1996), technological change is increasing (Sood & Tellis, 2005), innovation speed is increasing (Kessler & Bierly, 2002) and the speed of innovation diffusion has accelerated (Lee, 2003). R&D is a process aimed at discovering solutions to problems or creating new knowledge applicable to the company’s business needs that can provide a competitive advantage (Roussel, Saad, & Erickson, 1991). While the rewards can be very high, the process of innovation (of which R&D is most of the time the first phase) is complex and risky. The majority of R&D projects fail to provide the expected financial results, and the successful projects (25 to 50 percent) must also pay for the projects that are unsuccessful or terminated early by management (Kaiser et al., 2008). For this reason, a company's R&D efforts must be carefully organized and R&D investments must be deployed more effectively – that is more strategically and more efficiently. Deciding what R&D to undertake and at what priority is one of the most complex and critical decisions management faces today. Increasingly, organizations realize that the most decisive factor in the overall success of R&D is the selection of strategically worthwhile R&D goals. Rohrbeck and Gemünden (2011) showed that corporate foresight, which includes besides other tools scenario analysis, contributes to the innovation capability of a company within three roles. In the strategist role it directs innovation activities by creating a vision and providing strategic guidance, in an initiator role to trigger innovation initiatives and to increase the number of ideas, and in an opponent role to challenge basic assumptions and the state-of-the-art of current R&D projects to enhance the quality of their output. In the course of this thesis a tailored scenario process is showed that builds upon these three roles. Within the strategic scope new markets, new technologies and the complex interaction of other social, economic and political trends are investigated. Scenario planning in combination with requirements analysis and a material scanning offers a systematic approach to generate new material ideas for the future. By placing the employees of the R&D department in different future worlds, their basic assumptions are challenged. It can be concluded that long-term scenario thinking is becoming more important in generating innovations (von der Gracht, Vennemann, & Darkow, 2010).

In requirements engineering scenarios also contribute to innovation but without taking the long-term future into account. An introduction to the use of scenarios in requirements engineering is given in the next subchapter.

2.4 SCENARIOS AS REQUIREMENTS ANALYSIS TOOL

Almost all new activities, new products and new projects in the workplace are created in response to a business need. Yet situations where, despite spending tremendous time and resources, there is a mismatch between what has been designed and what is actually needed are common. Requirements analysis, also called requirements engineering, is the process of determining user expectations and system requirements for a new or modified product (Alexander, 2004).

In engineering, scenarios are increasingly used as a requirements analysis tool for system development (Robertson, 2004). Scenarios are a powerful antidote to the complexity of the environment and the systems that are influenced by it. People are very good at reasoning from even quite abstract scenarios, for example detecting inconsistencies, omissions, and threats with little effort. Scenarios use an uncomplicated, traditional activity – storytelling – to provide a vital missing element, namely a better view of the whole of a situation (Sommerville & Sawyer, 2006). A key strength of the scenario approach is the way that it encourages us to look at the whole problem before diving into possible solutions (Alexander, 2004).

Requirements analysis is mainly used in software development, but is coming in favor in various other branches of engineering. Jarke (1999) gives an overview of the possible contents, the knowledge expressed in the scenario, in scenario-based engineering. Scenarios can either focus on the description of system functionality, represent the context of the system, or they can address the interaction between the system and its environment. The interaction between a system and a user in a context is also called use scenario (Rolland et al., 1998). However, in the case of this study showing possible designs of the system might be dangerous because they focus the attention sharply on the form and details of the system when those specifications are not yet decided on and can even be important door opener to new possibilities.

In the course of system development requirements and assumptions are recorded at a point in time. This point of time usually is the moment at which the system is to enter service: at that time each requirement can be shown to be met by a combination of system behavior and the assumptions about the environment. But the assumptions about the environment are based on the current environment with its current customers. This differentiates the classical requirements analysis from the way requirements analysis is used in this study. At some future moment the requirements and assumptions derived from the current environment are no longer valid. The usual road in requirements engineering goes from knowing what the system should do to use cases and system design. But sometimes this may be hampered as we do not know what the environment will look like in the future. Scenarios that picture the future can help to overcome this barrier.

2.5 SCENARIOS AS REQUIREMENTS ANALYSIS TOOL FOR ALTERNATIVE FUTURES

With an accelerating pace of change in economic forces and improvements in technology, customer needs, political regulations and the resulting product and system requirements alter more quickly in response (Wiehler, 2004). As the environment of a system changes, the requirements for the system eventually become invalid or alter. In addition, the functional capability of the system must continually increase to maintain user satisfaction (Lehman & Belady, 1985). Certainly, the changes to the requirements that will occur in the future are uncertain. We cannot predict them precisely neither can we identify all possible future developments. However, what we can do is to examine a number of representative possibilities (America, Hamme, Ionita, Obbink, & Rommes, 2004).

Surprisingly, a combination of the two application areas of scenarios is rare. This subchapter explicates the exceptions in the literature by Potter and Roy (2000), Bush (2004) and Haaker and van Buuren (2005) where scenarios are used in conjunction with future requirements. Appendix A displays a comparison of the studies, including this study.

The studies investigate the requirements of completely different systems. All systems have in common that they are architecturally complex. Like stated before, scenarios are a powerful antidote to reduce complexity. Using scenarios to identify requirements is time consuming, both to establish the scenarios and to carry out the assessment. The studies focus on systems with a lifetime from approx. five years. Another characteristic the four applications of scenarios have in common is that they are highly sensitive to external factors, such as international agreements, government policy and regulation as well as public attitudes. That leads to the conclusion that the application of future scenarios for requirements analysis is worthwhile for systems that have a complex architecture, a long lifetime and are sensitive to external factors.

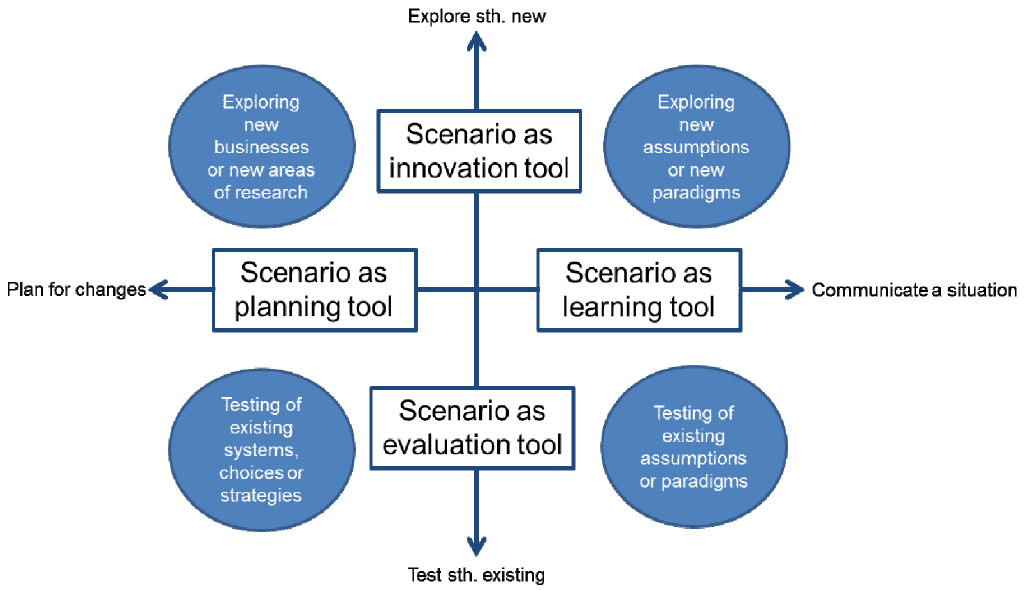
This study ventures to think in a timeframe that is almost double as long as those of the other studies, which comes with a very high uncertainty but enables to detect requirements very early. The form of the scenarios is solely a narrative description in all of the studies except this one. Narrative descriptions are used very frequently because they do not require many resources and force a high amount of concretion. The inclusion of visualization and figurative elements increases the reception value of scenarios and therefore a visual form of scenarios is applied in this study. Whereas the content of the other scenarios is the interaction between the system and its environment, this research enables to focus on the context of the system to test existing requirements and derive new ones. The intention behind it is that the participants should not have a predefined picture of the future automobile in their head but be instead creative and think of new possibilities. That is not possible in scenarios that give the participants a picture or description about how the system will look like and/or work in the future. The scenarios are therefore in general partial and leave properties about the intended system implicit.

2.6 CONCLUSION: SCENARIOS AS MULTI-SIDED TOOL

The literature review gave an overview about the multi-sided application fields of scenarios. Scenarios can be, on the one hand, used to plan e.g. a strategy, decisions or a system. Scenarios are employed in the processes of arriving at decisions and carrying out strategic planning inasmuch as they mediate points of orientation to those carrying out the planning and provide direction (Braun, Glauner, & Zweck, 2005). Here, the process serves the results. On the other hand, scenarios function as learning tool that stimulate processes of thinking, reflection and collective learning and function as simple communication tools. The scenarios are used here to jointly develop new images of the future inasmuch as they build upon an assessment of future relevant factors, they force us to make explicit existing (implicit or even subconscious) basic assumptions about future developments (Shell International, 2003). They also serve to focus attention on possible paths of development, salient characteristics, and the interactions of key factors, along with the range of possible eventualities (Braun et al., 2005). Scenarios serve to stimulate a discourse in which they help to promote a common, shared understanding of a problem while also promoting an exchange of ideas and the integration of different perspectives concerning a topic. In this way, they can bring a focus to communication processes while improving them, thus contributing to better cooperation among the different persons who are actively involved (e.g. among experts from different areas, Gaßner & Steinmüller, 2006). In this case, the process is often more important than the result. Additionally, scenarios can be used for innovation with the aim to develop or explore something new. The focus is on the identification of opportunities. The scenarios are used as design studios that inspire people to develop creative ideas and act entrepreneurially. Becker (2002, p. 9) calls them *“innovation catalyzer”*, a term that vividly captures the spark that can be created when future developments are discussed that lead to innovative ideas supported by a strategic foundation so that the ideas have a higher chance of becoming an innovation - more than just an invention. Furthermore are scenarios used for evaluation by testing the robustness of current specifications e.g. of a system, a strategy or an assumption. This is done by comparing the existing in the light of the future.

Fig. 1 displays the different application fields with their objectives.

Figure 1: Scenarios as multi-sided tool



Source: Compiled by the author (loosely based on Goetheer, Heijs, & Oelen, 2010).

But it is also important to emphasize that scenarios are not a kind of universal methodological tool; there is no one scenario approach that can be used for every analysis. This study aims at using scenarios as planning tool for a research strategy to identify relevant areas of strategic research. The scenarios furthermore have to function as learning tool by stimulating experts and other participating employees with processes of thinking and reflection. They should focus attention to possible paths of development and emphasize the interaction of influencing factors. Thereby they work as a communication tool for complex contexts. In addition currently applied materials have to be tested for their robustness, demanding scenarios to work as an evaluation tool. And finally should the scenarios be the innovation catalyzer with the aim to explore new material opportunities and aid the development of a new material solution.

Therefore it is very important to compose an approach which can provide all four of the functions described above at one and the same time. Which approach of the various methods of scenarios is used is explained in detail in Chapter 3.1

3 THE OVERALL PROCESS DESIGN

Scenario analysis has expanded notably in its 50-year history, thus by today a large diversity can be noticed in the scenarios that are developed (van Notten, Rotmans, van Asselt, & Rothman, 2003). To counteract the problem about the confusion over various methods of scenarios (Bishop et al., 2007) an overview of this diversity is presented and, in this context, an argumentation for the method used is given. Scenarios are utilized to attain different goals and therefore meet the need for different functions (Greeuw et al., 2000; Kosow & Gassner, 2008a). The first subchapter outlines different scenario types and focuses on the selection of the scenario analysis approach. The second subchapter explains the whole process of this study. The expectation for the research process is that it should enable the identification of future material requirements in alternative futures and scann for a material solution. The chapter includes a desciption of the tailored process applied to conduct this study. It is divided into three parts: the scenario analysis, the requirements analysis and the material scanning.

3.1 CHOOSING A SCENARIO APPROACH

A fundamental problem that occurs is that up to now no systematic and detailed set of criteria to select the appropriate method are available (Kosow & Gassner, 2008a; Mietzner & Reger, 2009b). There are no easy-to-apply, overview-oriented typologies which enable to state the goals, functions and resources and draw the suitable method from the typology. Besides, many scenario methods have never been applied in practice and methodological procedures of existing studies are often not transparent. Detailed toolkits for the practical implementation of scenario methods are almost generally missing (Kosow & Gassner, 2008b). Additionally, forms of “best practice” examples for the various methods that have successfully been used are nowhere to be found (Mietzner & Reger, 2005). This is mostly because each individual scenario process is in the rule so specific that an individual decision must be made from case to case concerning which concrete methods are most appropriate (Kosow & Gassner, 2008a). Nevertheless, some authors provide tables (Mietzner & Reger, 2009b), checklists (Kosow & Gassner, 2008a) or a cartwheel (van Notten et al., 2003) to help selecting the appropriate method.

Based on the existing literature, two different schools of thought in scenario planning can be identified: systematic-formalized and intuitive scenario approaches (Götze, 1991; van Notten, Rotmans, van Asselt, & Rothman, 2003; Strolz, 2007; Simon, 2011). In systematic-formalized methods[2] mathematical algorithms are applied to manage complex alternative futures. They are detailed in their definition of individual key factors and permit a comprehensive inspection of individual developments. Intuitive methods[3] scenarios are solely developed through the evaluation of individuals or groups (Richter, 2010). Their selection of key factors does not have to be very explicit and allows considering more aspects. The great advantage of the highly formalised method is that it allows control of the process. The disadvantage is that if it is not contained within certain limits it is the formalisation itself, which goes out of control and gains an excessive edge on the usefulness and reliability of the content. A number of experts is quite positive on the method, pointing out that it is often a good point of entry to begin with scenarios, that it arouses the interest of people of various backgrounds and that it is very good for stimulating new ideas. Intuitive approaches have the advantage that every available piece of information about the future can be integrated and new ideas are generated. On the other hand intuitive approaches are strictly connected with the experts working on the scenario, the methods are assembled together in the most varied way and thus make it difficult to check the credibility of the particular approach adopted from a scientific point of view (Mietzner & Reger, 2005).

Mietzner (2009b) offers a criteria grid with the most detail, which serves as a basis in this study to select the appropriate method. After the context evaluation, it becomes possible to decide on either an intuitive or a systematic-formalized method. The framework for the design to be developed is determined by this decision. However, the grid can only help to structure the scenario approach, but is not able to give a concrete recommendation for a certain scenario method. Nevertheless can the grid be used to compare the own conditions and goals with several scenario methods to select the most appropriate one. The applied criteria grid is available in Appendix B.

The systematic-formalized method is chosen in this study due to a better traceability. The transparency of the analysis method increases credibility and acceptance, whereas a decision for an intuitive development of the scenarios has to face criticism concerning the higher subjectivity (Mietzner & Reger, 2009a). The department for which the scenario analysis is conducted has almost no experience with scenarios. As the main part of the analysis is carried out by the researcher, the demonstration of the results of each process step of the systematic-formalized approach is a good possibility to secure a high robustness of the results. The department mainly consists of engineers and natural scientists that are used to work with

[2] This approach goes back, for example, to the tradition of the Batelle Institute (Frankfurt) and is linked among others with the names of von Reibnitz (1991) and Geschka / Hammer (1983); the techniques are presently employed in the scenario techniques of ScMI (Gausemeier), z-Punkt (Burmeister) and the Futures Group (Gordon).
[3] This approach is associated with the techniques of GBN (Schwartz (1996), van der Heijden (2009) and Shoemaker (2002).

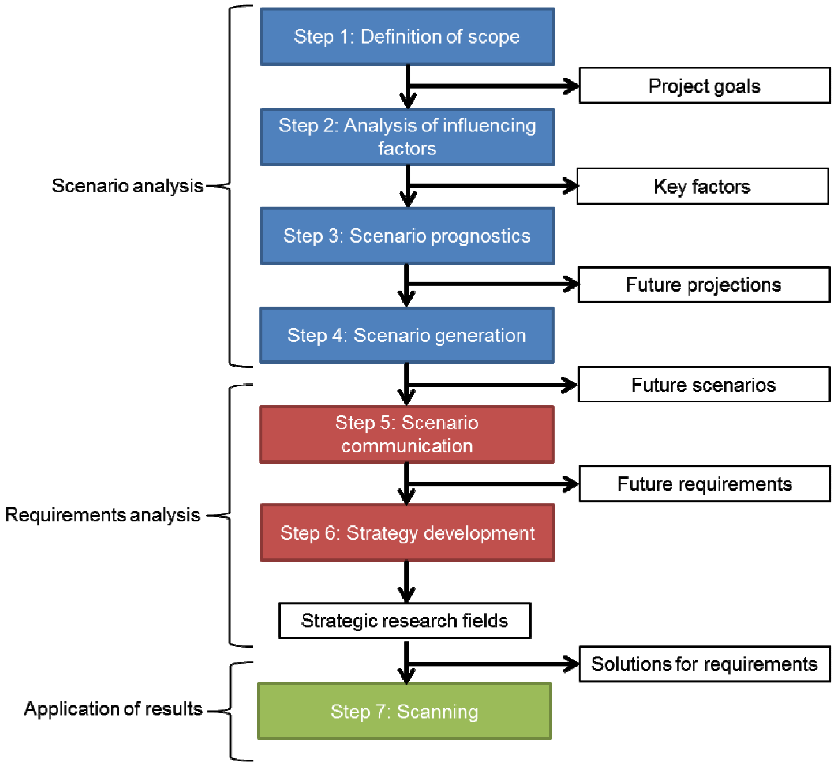
systematic and mathematical models. Therefore, it is assumed that a systematic-formalized method reaches a higher acceptance and legitimacy. Furthermore, it is particularly important for the strategy development to understand the dynamics in the environment. The interdependence between influence factors plays a growing role (Gausemeier et al., 1998), thus, organizations have to think in structures of linked influences (Wulf et al., 2011). The structure of the environment, i.e., the network of relationships between these elements, is essential to understand its evolution, because this structure maintains a certain permanence (Godet, 1987). It is argued that it is not enough to describe the environment of the automobile interior as a simple space but instead to support the systematic vision into the future with networked thinking. However, systematic-formalized scenario methods also contain some subjective and intuitive aspects, e.g. both in their definition of the main characteristics of key factors and in the selection of scenarios (Kosow & Gassner, 2008a).

Numerous variations of the systematic-formalized approach have been published, each identifying a number of discrete steps, varying in the number of steps, depending on what features of scenarios are highlighted or ignored (von Reibnitz, 1991; Gordon, 1994; Gordon; Godet, 2001¸ Phelps, Chan, & Kapsalis, 2001; Fink et al., 2002; Burmeister, Neef, & Beyers, 2004; Gausemeier et al., 2009). Here, too, provides Mietzner a useful overview (Mietzner & Reger, 2009a).

The approach by Gausemeier and Fink (1998) is chosen because the number of scenarios are not predetermined and are a result of the analysis, it focuses on descriptive scenarios and can be used for an orientation problem and not only for decision problems, it makes sense to be conducted only with macro-environmental factors, the inclusion of existing scenarios and quantitative factors is possible, a permanent trend monitoring is not necessary, it requires an adequate resource and time effort, experts can be included in steps that do not cost too much time and the required software is available to the researcher. Nevertheless it is of central importance to adjust the procedural steps to existing resources and underlying conditions, while simultaneously making them as simple and robust as possible (Burmeister et al., 2004).

Scenario planning mostly consists of two parts: first, scenarios are developed through a systematic process of picturing future situations; second, strategic planning is based on the outcome of scenario development (Bishop et al., 2007; Lindgren & Bandhold, 2003; von der Gracht & Darkow, 2010). To derive a research strategy for material, requirements analysis is needed to identify future material requirements. Without this step it is not possible to infer new fields of research for material from developments in the macro environment.

Figure 2: The seven steps of this study



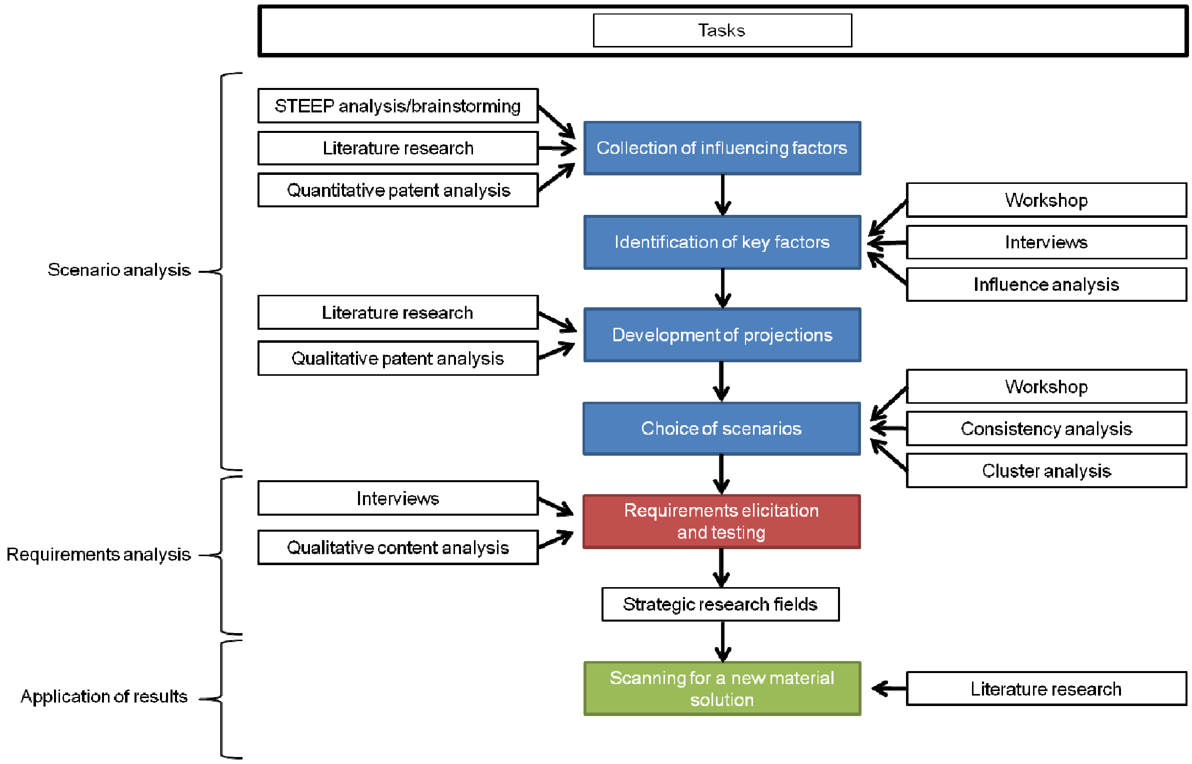
Source: Compiled by the author (based on Fink et al. 2002 and Gausemeier et al. 2009).

Fig. 2 gives an overview of the consecutive steps and their results. Step 1 restricts the scope of the scenario analysis, in step 2 influencing factors of the automobile interior are collected, analyzed and the most important ones selected, step 3 projects the selected factors into the future, in step 4 scenarios for further analysis have to be chosen, in step 5 the scenarios are communicated and a requirements analysis is conducted, step 6 displays the results of the analysis and in step 7 one solution for the requirements is searched for in other industries as an example how to make use of the results.

3.1 THE PROCESS

There may be many approaches available, from which only a limited amount makes sense given the boundary conditions. The set-up and schedule of the project at the Daimler AG are such conditions, as well as the limited resources and time available for the master thesis. Another condition is the requirement to have theory and expertise incorporated.

Figure 3: Overview of the data collection and analysis methods used



Scenarios, which are highly varied but provide a consistent, thus coherent and meaningful, picture of the future, are developed concerning a defined question or topic. Robustness is tried to be maximised by participation of different expert knowledge from different positions. Thus the implementation of a high number of very different perspectives into the process is enabled. Fig. 3 displays the process and the data collection and analysis methods used in each of the steps to answer the research questions.

The year 2030 was chosen for this study because strategic planning in the automotive industry has already quite long planning horizons. It takes ten years from research to serial production and shorter timeframes are unnecessary as they are covered with the usual planning procedure. 18 years is the timeframe in which it is assumed that the first major changes triggered by environmental factors become apparent. A longer timeframe would have been also interesting, though are technological developments for such a distant point in time very hard to envisage. Furthermore, 2030 is a round number used in many future studies and thus a wise date to be able to integrate and compare those studies. Additionally, the long timeframe of 18 years does not allow solely the extrapolation of current developments and trends, but instead stimulates farsightedness and imaginativeness. The automotive industry is used to a generally stable environment, however it is assumed that in the next 15 to 20 years the industry will experience an enormous change amongst other factors due to questions about the long-term availability of fossil fuels and a switch to new market areas (Barthel et al., 2010).

The pictures of the future are globally oriented but also take regional aspects into consideration to be able to assess global developments and identify new opportunities outside of the German market. But as it is not possible to present changes in all countries, the focus mostly lies on Germany as the country in which headquarters is located and the research takes place and the BRIC countries representing the most confident sales market. A scenario in terms of a picture of the future illustrates the condition at a specific point in time, which describes the most important influencing factors and has been developed to this specific point through the co-activation and interaction of various factors.

The study is restricted to personal vehicles, thus utility vehicles are not considered. This is due to the fact that utility vehicles have a different purpose and a different form than personal vehicles and therefore might have quite other influencing factors. However, it is not differentiated between personal vehicle categories as this would induce the participants to have a predetermined picture of a certain vehicle model and hinder creativity. Furthermore might the vehicle categories be completely different in the year 2030. The project concerns only the interior of a passenger car, other areas of the car are not considered. However, the scenarios do not display the interior itself but instead focus on developments that surround the automobile interior.

3.1.1 Part 1: Scenario analysis

For the elaboration of global scenarios a systematic process was followed to assure credibility and dependability of data as well as good scenario quality. Scenarios, which are highly varied but provide a consistent, thus coherent and meaningful, picture of the future, are developed concerning a defined question or topic. Robustness is tried to be maximised by the implementation of a high number of very different perspectives into the scenario process. The results of prior futures studies and previously developed scenarios are considered in order to achieve consistency; therefore desk research is an essential early step in level one.

3.1.1.1 Collection of influencing factors

Influencing factors are the *“central factors which together form a description of the scenario field while also having an impact on the field itself and/or serving as means for the field to have an impact on the world around it”* (Kosow & Gassner, 2008a, p. 26). As the scenario field is too complex to intuitively derive influencing factors, it is divided into different influencing areas. In the case of this thesis, areas of the global environment are chosen. The current developments that are responsible for the enormous change in the automotive industry and that will also have an effect on the interior are mostly global developments that will affect the meso and micro level. The study uses first a discursive approach to systematically structure the environment of the automobiel industry. STEEP analysis was applied as central framework. It stands for political, economic, social and technological analysis (Zegras et al., 2004; Wilson & Gilligan) and is a useful tool for understanding the “big picture” of the environment in which an object is situated that prevents that major aspects of the general environment are overlooked. The growing importance of ecological factors in this century has encouraged widespread use this updated version of the PEST framework. Furthermore, a creative approach to collect more influencing factors with a brainstorming session by the author was conducted.

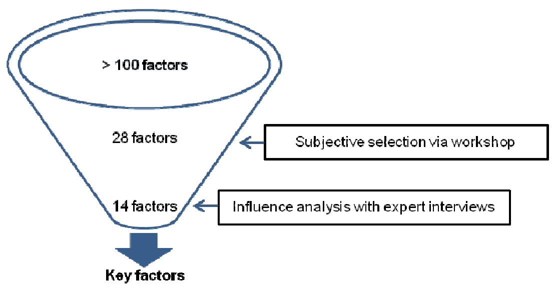
Shoemaker (1995) suggests to start with trend studies and scenarios that others have developed, when the scenario scope lies in an area with already conducted studies transcending the topic. This study acts on the suggestion and is based on trend studies and already conducted scenario analyses that are linked to the automobile interior of the future. Because performing a trend analysis and the development of a scenario set needs much expertise and is time consuming, gathering all existing scenario analyses gives a good starting point. It is especially valuable as the study focuses on macro developments, which are mostly covered by those trend studies. By doing this it is possible to build a high quality and reliable overview of trends. Also, the already developed scenario sets can often be reused and adapted to the desired specific context (Goetheer et al., 2010). The studies were identified through internet and intranet research as well as cross-references as proposed by Kosow and Gassner (Kosow & Gassner, 2008a). It was also made use of the knowledge database with studies concerning the automotive industry and a rubric especially for trends and innovation that the Daimler AG maintains. The studies were selected in accordance with the STEEP framework and focus on various fields of the future e.g. mobility, mindsets and consumer attitudes or pollution of the environment. The list of the trend studies and scenario analyses taken into consideration can be found in Appendix C.

The impact of technological change is more difficult to predict than some of the other influences (International Council for Science, 2011), but technological developments are important for the progression of the vehicle interior. For that reason, a patent frequency analysis by keyword was conducted to confirm technology trends particularly in the field of the automobile interior. Patents are a significant way of disclosing science and technology progress in the society (Lee, Su, & Wu, 2010). The number of patents present per year characterizes the trend development and corresponds with a parallel form to the technology life cycle. Patent analyses can contribute to a comprehensive and objective picture of activity on a certain field of technology (Acatech & Fraunhofer IRB, 2008).

3.1.1.2 Identification of key factors

To use all of the identified factors in scenario creation would lead to scenarios that are too complex (von Reibnitz, 1991). From the large pool of influencing factors those factors which are especially characteristic for the development of the issue of concern had to be selected. Two methods are common to identify the most relevant factors. Factors can either be selected subjectively or a systematic influence analysis is conducted (Wulf, Brands, & Meißner, 2011). This study uses both methods – a workshop with the department the scenario analysis is done for and an influence analysis via expert interviews. Fig. 4 is an overview of the applied key factor selection process.

Figure 4: Applied key factor selection process



In the workshop with the team “Interior Materials, Manufacturing and Concepts” the available factors were filtered and consolidated in terms of logic and structure. To reduce the extensive pool of influencing factors, a shorter and more comprehensible list of factors was consolidated. The reduction was conducted according to the question which factors they consider to be especially important for the future of the automobile interior and the material that is used in it. Aim was to reach a mutual agreement. Consistent with the opinion of the group a list of the most important factors was developed. This step was necessary as over 100 factors had been identified. It would have not been possible to interview experts to the interdependence of 10 000 factor pairs and risk non-participation. Expert knowledge was integrated in this step as assumptions about the interdependencies between the factors demand fundamental knowledge (Kosow & Gassner, 2008b), where experts can give useful input. An influence matrix was used as a means for systematically identifying the interactions and the dynamics of factors. This was done by listing the factors already identified in a matrix of columns and rows, in both cases in the same order of succession. In this way, each factor is juxtaposed with all of the others. Separate interviews were conducted, where the experts individually filled in the matrix.

For a better overview the factors were displayed in an active-passive-grid, where each factor is positioned according to its behavior in relation to the other factors. Parmenides EIDOS 8.0 was used to graphically plot the factors in the active-passive-grid. Traditionally, the factors are directly displayed with their absolute active and passive sums in the active-passive-grid, however this study followed the opinion of Richter (2010) who criticizes that in this variant the positioning is strongly dependent on the maximum values and uneven data distances between the factors could distort the result. Therefore, the factors were positioned according to the ranking of their sums. Generally it can be said that the relatively active factors have the strongest links to the other factors, which means that changes in those factors will have the most influence on the other barriers and driving forces of the problem. Therefore, concentrating attention on these key factors has the most significant impact on the project. The relatively passive factors only have an effect on a limited part of the other factors (von Reibnitz, 1991; Mietzner & Reger, 2009b) and should rather not be chosen. These passive factors can also be excluded because their developments can later more easily be integrated in the projections of the more active factors. To identify the most suitable key factors the detailed selection method by Fink and Siebe (2006) was applied (Fig. 5).

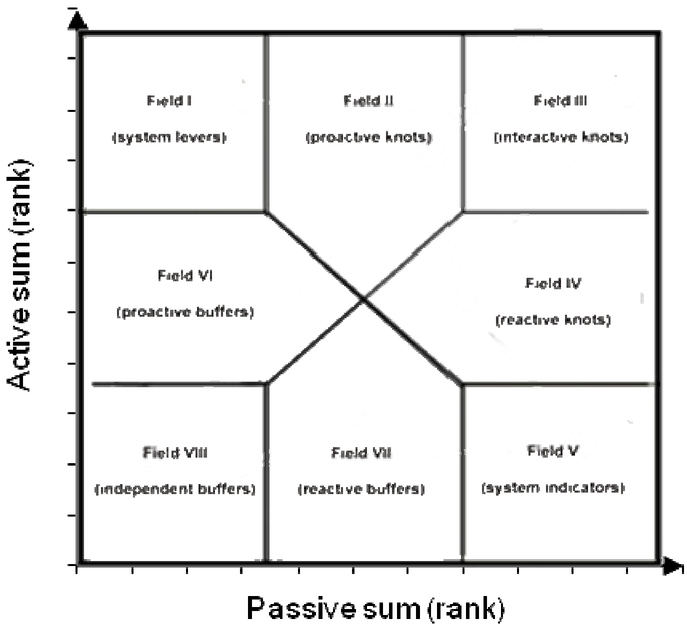
- System levers[4] (field I) possess a high active but a low passive sum and thus exercise a strong influence over the analyzed system, while they are themselves almost not influenced by it. Changes in those factors have an effect on many of the other factors.
- Proactive knots (field II) have high lever forces that can be slightly compensated by the system dynamics.
- Interactive knots (field III) have a high active and passive sum and are therefore strongly integrated in the systemic nature, which means they are very highly networked with other factors. Changes in those factors have to be monitored because they can have unexpected effects.
- Reactive knots (field IV) are reactive with medium activity. Here, influencing factors are often to be found with which consequences of the system dynamics can be described.
- System indicators (field V) possess a low active but a high passive sum and are thus extremely reactive. System changes can be read off these factors early.
- Proactive buffers (field VI) are factors with a medium activity and a low passivity. Sometimes hidden lever forces can be found in this field.
- Reactive buffers (field VII) are factors with a low activity and a medium passiveness. They are only very rarely of interest.
- Independent buffers (field VIII) have a low active and passive sum and influence the system only little or do not belong to the system.

[4] The term „system“ that is used by Fink and Siebe to describe the net of influencing factors and its dynamics has to be delineated from the term „system“ that describes the product that is developed in requirements engineering and that is used in this study to refer to the automobile interior. The word is not replaced with a synonym

On the basis of this classification four characteristic and overlapping areas can be identified in sum:

- Proactive factors (fields I, II and VI) have a strong influence on the analyzed net of factors, while they are only slightly influenced by it. Those factors are typical operating levers and ideal for steering interventions.
- Interactive factors (fields II, III and IV) are strongly networked with other factors, express a large part of the system dynamics and are for this reason ideal key factors for the development of scenarios.
- Reactive factors (fields IV, V, and VII) are not very active and are strongly influenced by other factors. Those are factors which change quickly with transformations in the net of factors but are rather not of interest for long-term considerations.
- Independent factors (fields VI, VII and VIII) have only a very low activity and passivity and have almost no influence on the net of factors.

Figure 5: Active-passive-grid



Source: Fink et al., 2002.

3.1.1.3 Development of projections

In order to present different points of view regarding the development perspectives of the selected key factors, alternative projections were consciously built. Goal was to overcome traditional modes of thinking in relation to the development perspectives of each key factor and to expose the “area of possibility”. It is therefore reasonable to describe from today’s perspective plausible but also extreme yet imaginable projections. The development of projections in this study is based on two sources: a literature research to identify different opinions to the development of factors in trend studies and scenarios and a qualitative patent analysis for the technological developments that is based on the already identified patents in the previous step. To create a great variety of projections they were developed according to the suggestions by Gausemeier et al. (2009). The future projections display both trend progressions as well as some out-of-the-box developments. Quantitative prognoses and qualitative projections were integrated to utilize this critical strength of scenario analysis. Factors that can be described quantitatively were expressed in numbers. But as these numbers are not able to vividly display the future space, they were always combined with qualitative descriptions. However, also intuitive and creative aspects were contained to fill the area of possibility. For a better ease of use, concise short titles to spark the applicants' interest and to quickly adopt in discussion were applied. The future projections were described and reasoned in such a way that they are understood easily even by third parties. These text modules are later fallen back on to describe the scenarios.

Pretesting to ensure dependability as well as credibility was performed by one of the supervisors of the thesis. First, after their initial formulation, the projections were checked for completeness and plausibility of the content as well as methodological soundness. The formulation of projections directly impacts the quality of the entire study (Mićić, 2007). To ensure methodological rigor, the following measures were employed: first, the projections were checked for ambiguity and precise wording was used to guarantee specificity in formulation (Salancik, Wenger, & Helfer, 1971). Second, conditional statements were avoided that dependent on the fulfillment of a series of conditions. Third, the projections were structured into clusters of topics to make it easy to follow, according to the terms in the STEEP analysis.

3.1.1.4 Choice of scenarios

Even though many scenarios are often conceivable in theory, the number of scenarios that can be processed cognitively is limited (Kosow & Gassner, 2008a). Therefore, this step includes the bundling of projections with a consistency analysis, in which projection pairs are checked for consistency. The inductive approach was used because analytically precise and to a larger extent objectified results are expected by the target group of the scenario analysis and to avoid being misled to a preconceived ideal of the future. Furthermore, makes the large number of key factors the application of the deductive method very difficult. Expert opinion was included with a workshop to avoid that the bundling of projections is based on one subjective evaluation and to incite a systematic discussion of future-oriented relationships that lead to a useful understanding of the complexity of relevant drivers behind the subsequent scenarios. The workshop was utilized to detect possible weak points in the projections once more and to eliminate subsequent interpretation problems. Participants of the workshop were the members of the department the scenario analysis was developed for.

Each projection pair was displayed on a screen and the participants were asked to discuss and evaluate their consistency. To help with judging the consistency of two alternatives, the participants were asked to imagine two newspapers in front of them, each with a different top headline. Each top headline is the name of an alternative from the alternative pair. When the two newspapers are placed next to each other, do the two headlines make sense together? How well or poorly do they fit? The following scale was used:

> -3 = strong inconsistency i.e. the two projections are absolutely mutually exclusive and cannot appear together in a plausible scenario.
> -2 = partial inconsistency i.e. the two projections contradict one another. Their combined occurrence influences the plausibility of a scenario strongly.
> -1 = minor inconsistency i.e. the two projections contradict one another slightly. Their combined occurrence influences the plausibility of a scenario slightly.
> 0 = neutral or independent i.e. the two projections do not influence each other and their combined occurrence does not influence the plausibility of a scenario.
> +1= minor mutual support i.e. the two projections can generally occur together in a scenario.
> +2 = strong mutual support i.e. the two projections make a good pair in a scenario
> +3 = very strong mutual support i.e. the combined occurrence of the two projections supports the strong plausibility of the scenario.[5]

The direction of impact does not have to be taken into consideration, thus it is sufficient to fill the area above the diagonal in the matrix. The consistency calculation was carried out by means of the Parmenides EIDOS tool. The software calculates with a full enumeration all possible scenario combinations with their overall internal consistencies. A ranking procedure was applied to identify those sets of factor characteristics which are particularly consistent. Parmenides EIDOS enables to display the scenarios in a cluster view, which was used to ease the selection.

The choice of scenarios was determined by three criteria: consistency, variety and challenge. The cluster view of the software is based on a complex projection algorithm and shows the 100 most consistent scenarios on a cluster map pooling single objects to clusters according to their similarity. First of all, distinct clusters were identified to avoid drafting several scenarios that are

[5] Note: The consistency evaluation scale by Parmenides EIDOS was combined with a, for this scale adjusted, description by Gausemeier et al. (2009).

simply slight variations on the same theme. Then it was looked for the most consistent scenarios in the cluster. The more consistent scenarios are, the bigger they are displayed in the cluster view. With the third measure trivial combinations of scenarios were avoided and interesting and challenging scenarios were chosen. However, like suggested by Gausemeier et al. (2009) the choice of scenarios was supported by software, but not determined by it.

3.1.2 Part 2: Requirements analysis

The following steps show how requirements can be analysed in alternative futures and areas for particular research attention can be derived. A specific characteristic of the applied method is that no use scenarios are utilized to derive the requirements and details to the development of the system are left implicit, which offers the possibility to identify new requirements for material even if details of the system e.g. form and size of the automobile interior cannot yet be defined.

3.1.2.1 Scenario visualization

The selected scenario bundles were formulated into scenarios with the aid of the determined interrelationships between the factors from the influence analysis that helped to bring the projections in a coherent picture. The scenarios in this study function as an instrument to describe the future macro environment surrounding the future automobile interior. Aim was to test and elicit requirements via expert interviews from the scenarios. As the audience of the scenarios did not take part in the scenario analysis, the scenarios had to be prepared in such a way that they support the imagination and understanding of the future environment. Furthermore was a design necessary that enables drawing conclusions about extremely diverting topics like the availability of the material used, the production process or the design. Complex information had to be presented quickly and clearly. A tool that is able to integrate detail where it is needed, is emotional and vivid and looks professional is the software “Prezi”, a presentation editor with a zoomable canvas. It is used in this study to present the scenarios as different worlds where the audience can walk through and receive information. Additionally, was a short written summary of each scenario handed out to the participants to get a better overview and an aid to remember the details. As recommended by van der Heijden (1998), a final check of the scenarios was conducted by the thesis supervisor to ensure compliance with quality criteria.

3.1.2.2 Requirements elicitation and testing

The requirements elicitation and testing was conducted via qualitative interviews that will be explained in more detail in Chapter 4.

The results of the previous steps established a strategic research agenda for the research department concerning material requirements that will need to be met in the future. New strategic activity fields for research whose development will be crucial during the next 18 years were suggested. To be able to quickly adapt to changes all scenarios were taken into account with their variations in conditions.

3.1.3 Part 3: Scanning for a new material solution

The scanning seeks out new and existing materials as a solution to the identified requirements, from private industry, university research, government labs, and international research entities, developed for another industry that could be applied in the automobile interior towards reaching goals, solving problems and creating opportunities. Due to time constraints, it was not possible to search for several solutions. Therefore, one example was used for demonstration. The material scanning was based on initial suggestions by experts during the interview and a following literature research, mainly internet-based. The house construction industry was chosen for the scanning because it was named for several requirements, works with a high variety of materials and the materials applied in this industry did significantly change in the last years (Peters, 2011). It was searched for materials that are able to fulfill a combination of the identified requirements.[6]

[6] The search term “Bauwirtschaft OR Hausbau OR Architektur OR building industry OR building construction OR architecture AND Material OR Werkstoffe OR substance AND Innovation OR Trend OR Neuheit OR novelty” was combined with each of the requirements in turn.

4 METHODOLOGY

Chapter 4 focuses on the main method of the study – the interviews and describes the interviews, the sample and the software that was applied.

4.1 EXPERT INTERVIEWS

Two interview rounds with experts were conducted during this study. The first one to derive information about the interconnections of the influencing factors, the second one to elicit and test material requirements.

4.1.1 First round of interviews

The first round of interviews was a combination between a questionnaire and an interview and used to integrate expert opinion into the key factor selection process by means of an influence matrix. While questionnaires can provide evidence of patterns amongst populations, qualitative interview data often gather more in-depth insights on participant attitudes and thoughts. The filling of the influence matrix equated a questionnaire as the question *“How strong influences factor a (row) factor b (column)?”* is answered quantitatively on a scale of four with: 0 = no influence; 1 = weak relationship; 2 = medium relationship; 3 = strong relationship. It is not relevant if the factor is positively or negatively influenced. A combination of the two methods was used in this case to understand the intention and thoughts behind the evaluation of the influences and therefore a more detailed answer about why and how the factors are connected can be gathered. The expert consultation started with a short presentation about the content and goals of the study and continued with the questioning procedure. A software developed by the target department of the scenario study was used to ease the process of filling in the matrix. The consultation was recorded to reconstruct the intention behind the decision statements to the influencing factors.

To analyze the filled matrices and calculate the group opinion the mean influence value across all experts was calculated for each factor pair. It was specifically checked for consensus, outliers and potential misunderstandings. Results of influences that indicated strong deviations between the expert opinions were looked at more closely with the related recordings. Goal of the influence analysis was to identify the behavior of all factors in relation to the other factors. The matrix with the influence data shows the active sum of each factor that indicates how strongly it influences other factors and a passive sum that indicates how strongly it is influenced by other factors.

4.1.2 Second round of interviews

The second round of interviews consisted exclusively of semi-structured qualitative expert interviews. Goal of the interviews was to test current materials and identify new material requirements in alternative futures. This interview style is suitable, because it is flexible, allows new questions to be brought up during the interview as a result of what the interviewee says, but ensures that the interview does not get lost in topics that are of no relevance and respects the time pressure experts usually have. The interviews were held face-to-face according to the interview rules as described by Kvale (2007) and Berg (2004). These rules imply working with an interview protocol.

The interviews started with a short introduction to the research and the interview itself to avoid misunderstandings. The interviewee was presented with the opportunity to ask questions and asked for permission to record the conversation to prevent data loss and increase credibility (Shofield, 2002). To get familiar with the material the expert works with and to make the interviewees comfortable with a topic they are familiar with, they were asked to describe the materials that are currently used in their field of expertise and the technologies applied to produce these materials. Then the first scenario was visualized for the participant or rather the participant could adjust the speed of the scenario visualization with the software “Prezi” to his/her own reading and speed of processing. After the scenario the expert was first asked to name those factors in the scenario that have the strongest influence on his/her choice of material and the factors that have no influence on the choice of material. These questions had two functions: first of all, they worked as a control mechanism to test if the factors included are relevant to the material used in the interior. The study includes materials for facing parts, structural parts, décor material and trim elements. These fields of materials all have different factors that influence them in particular. Secondly, it can be assessed where the focus of the interview is and gives the participant the opportunity to think all aspects of the scenario through. The next question asked specifically for the requirements the scenario places on the material (requirements elicitation). It was intended to ask for a prioritization of the requirements with a follow-up question, however, participants automatically prioritized the requirements. A high importance of the requirement means that it is a necessity for the material to fulfill this requirement in this scenario in order to be successful with the automobile interior. A medium importance reflects that the importance of this characteristic is mitigated by one or several developments in the scenario and can thus not have the highest priority. A low importance signals that the characteristic is either not required in the scenario or that it is only a nice-to-have characteristic. The participants were then requested to evaluate if the currently applied material is able to entirely fulfill those requirements (requirements testing). When the material was not able to fulfill the requirements more detail questions were posed why it is not able and where exactly the problem lies. These were the main questions of the interview and the basis of the requirements analysis. Afterwards, the respondents were asked to name other industries that are subject to the same or similar requirements, where they would search for solutions to fulfill those requirements in the specific case of this scenario. This process was repeated for all four scenarios. The final question posed after all the scenarios were watched, asked if there are other macro factors not displayed in the scenarios that might have a strong influence on their material in the future. This question acted as a control mechanism to test if all important factors were included in the scenarios. The interview guideline can be found in Appendix D. The interview was closed by thanking the participant. To avoid language barriers the interviews were conducted in German.

Gläser and Laudel (2010) suggest qualitative content analysis for the evaluation of expert interviews. This method analyzes texts by extracting information in a systematic procedure. For this purpose the text is scanned by means of an analytical framework for relevant information. The extracted information is assigned to the categories of the analytical framework and is processed relatively independent from the text - that is transformed, synthesized with other information, dismissed, etc. The method of analysis differs in two points from other qualitative methods. First, it does not cling to the source text, but works with the information separate from the text. The reference to the text is maintained, but all further steps of analysis are conducted with the separated information. Second, the category system is developed ex ante. The scheme for the in the text contained information is determined before the analysis of the data. This method was applied in the current study as it is possible to predefine the category system according to different requirements and it is easier to work only with the extracted information. However, the original method by Mayring (2007) was not used because it does not allow changing or adding categories to the category system. Instead, the study acts on the suggestion by Gläser and Laudel (2010) to be flexible in the category system. The analysis was conducted by means of the software “MIA”.

4.2 SELECTION OF EXPERTS

Scenario processes differ in the types of persons who participate in their development or evaluation. Depending on the degree of involvement, three rough types of participants may be distinguished: scientists / consultants, internal / external experts or persons actively involved or “those affected”: citizens, consumers, etc. (Kosow & Gassner, 2008a, p. 41). Bogner and Menz (2002, p. 46) define experts as individuals having *“process oriented and interpretive knowledge referring to their specific professional sphere of activity. Thus, expert knowledge does not only consist of systematized and reflexively accessible specialist knowledge, but also has the character of practical knowledge in big parts. Different and even disparate precepts for activities* *and individual rules of decision, collective orientations and social interpretive patterns are part of it".* The success of scenarios greatly depends on the choice of participants (Godet, 2001). Results can be biased by dominating competencies. Thus it is necessary to set up as multidisciplinary a team as possible.

The sampling of the units of observation for the first round of interviews was done on a non-probable basis and was purposive (Saunders, Lewis, & Thornhill, 2009). Purposive sampling enables to use the own judgement to select cases that are particularly informative. For the first round of expert consultation in order to identify key factors attention is paid to select experts in all influencing areas to approach the subject from different perspectives and achieve a balanced opinion. Required was a broad understanding of macro developments that affect the automotive industry. It was intended to include information-rich cases in the sample. The internal experts were selected according to their position and field of activity at the Daimler AG. Hints for possible external contacts arose from the literature research conducted for the influencing areas.

All participants were approached via telephone or email to arrange a face-to-face meeting. Two selected experts cancelled by reasons of illness, which resulted in a sample size of 13. The list of experts can be found in Table 1. The interviews took approx. 90 minutes.

Table 1: Overview of general experts

Due to confidentiality this part of the thesis has been excluded.

The selection of the second round of experts for the derivation of requirements in the scenarios was based on the intention to include specialists who do research or are responsible for a component in different areas of the automobile interior e.g. seat structure, doors, interior rear etc. The experts were also selected according to their field of activity at the Daimler AG, again purposive non-probability sampling was applied. The following questions were asked during the selection process: Who has the relevant information? Who is most likely able to give precise information? Who is most likely willing to give information? Who is available? (Gorden, 1975). Participants were approached via telephone to arrange the meeting for the interview. The sample size was twelve (N=12) with the number of experts in each material category being chosen according to its share in the interior (Table 2). Interviews were conducted until data saturation was reached and the additional data collected provided no new insights on material requirements. Each interview lasted from 1 to 2 hours.

Table 2: Overview of specialized experts

Due to confidentiality this part of the thesis has been excluded.

4.3 SOFTWARE USED

Four software tools were utilized in this study. The first one was developed by one of the members of the department the scenarios were created for. Based on the application development system "Visual Studio", it supports the filling of the influence matrix by leading through the process and giving additional information to the influencing factors. The software juxtaposes two factors and presents a short description to each factor. Four buttons indicate the influence possibilities: no influence, weak, middle and strong influence. The strength of influence is automatically transferred into an Excel matrix. With the software time is saved and mistakes due to shifting in line are prevented. Appendix E displays an example of the software with two juxtaposed factors that was used to fill in the matrix.

The program Parmenides EIDOS 8.0 is a tool to assist in complex decision-making. It can be used when developing scenarios, corporate strategy and other decision-making by supporting thought development through visualizations of links and results. In this study it was utilized to define the key factors in a complex macro environment, to assess the consistency of scenarios and to draw a cluster map of the most consistent scenarios. There are other software tools like INKA, Szenario.Plus or Szeno-Plan that offer similar functions. The software Parmenides EIDOS was chosen because it was available to the researcher and enables all the functions necessary to conduct this study.

Prezi is a cloud-based presentation software and storytelling tool for exploring and sharing ideas on a virtual canvas. It is distinguished by its Zooming User Interface (ZUI), which allows users to zoom in and out of their presentation media and enables to display and navigate through information within a 2.5D space on the z-axis. The software was used to display the scenarios and enabled the participants to walk through four different future worlds.

"MIA – Makrosammlung für die qualitative Inhalts-Analyse" is a software based on "Visual Basic" to create extraction macros specifically for the own research question. These macros support the extraction of information from the text and the separate, structured in its content storing of information. In this study it was used to support the qualitative content analysis.

5 RESEARCH RESULTS

Due to confidentiality this part of the thesis has been excluded.

6 RECOMMENDATIONS FOR THE DAIMLER AG

Due to confidentiality this part of the thesis has been excluded.

7 CONCLUSION AND DISCUSSION

Due to confidentiality this part of the thesis has been excluded.

APPENDIX A: OVERVIEW OF STUDIES THAT USE FUTURE SCENARIOS FOR REQUIREMENTS ANALYSIS

Table 3: Overview of studies that use future scenarios for requirements analysis

	Bush (2004)	Haaker & van Buuren (2005)	Potter & Roy (2000)	This study (2012)
Title	Alternative world scenarios to assess requirements stability	Future scenarios approach for aiding the design of innovative systems	Using scenarios to identify innovation priorities in the UK railway industry	Scenario planning for material strategy derivation – the automobile interior 2030
Subject matter	The current product is positioned in future scenarios to identify those requirements that are potentially unstable, evaluate their importance and choose between alternatives	Use scenarios are positioned in future scenarios to check if the future assumptions are compatible with the intended system functions	Alternative business environments with use scenarios are developed to derive customer needs and the key technologies required in each scenario	The currently used interior and its material is positioned in future scenarios to check if it is compatible and which new requirements can be derived
Intention	Test if Minimum Safe Altitude Warning system, used to warn pilots flying below a safe altitude, is future proof	Design of a system for mobile enabled secure exchange of content	Identify areas of strategic R&D in the UK railway industry	Identify areas of strategic R&D concerning the material used in the automobile interior
Process/ methodology	Intuitive methodology by van der Heijden (1998): identification of two key uncertainties to build four scenarios	Intuitive methodology by van der Heijden (1998): identification of two key uncertainties to build four scenarios	Systematic-formalized method similar to the one by the Futures Group (Ringland, 1998): Extrapolation of trends and identification of events that could disrupt them to build four scenarios	Systematic-formalized method by Gausemeier et al. (2009): influence analysis, projections, consistency analysis
Timeframe	System lifetime	5 years	10 years	18 years

Form of scenarios	Narrative description, formal notations	Narrative description, informal notations	Narrative description, informal notations	Visual description and narrative description, informal notations
Content	Interaction between system and its environment	Interaction between system and its environment	Interaction between system and its environment	Context of the system
Purpose	Assess requirements stability	Assess requirements stability	Assess requirements stability and elicit new requirements	Assess requirements stability and elicit new requirements

Source: Compiled by the author.

APPENDIX B: APPLIED CRITERIA GRID

Table 4: Applied criteria grid (situation for this study in red)

Initial situation	**Organization/corporate association**	Company	Method is used within a company for a strategic business unit	Method is used for several connected organizations in an industry	Project with organizations in different industries		
	Problem statement	Decision problem	Orientation problem				
	Content and source of information	Developed topic	Diffuse topic	Information for appraisal is available	None/little infomation is available		
	Consideration of existing scenarios	Consideration of already existing scenarios (e.g. technology or global scenarios)	No consideration of other scenarios	Existing scenario as source of scenario planning			
	Future orientation as part of the corporate philosophy	Future orientation is anchored in the corporate identity	Application of future research methods	Trend monitoring	Marginal future orientation		
	Experience with scenarios analyses	Regular use of methods	Use of methods with the support of an external partner	External assignment of scenarios analyses	No experience with scenario analyses	Experience only within a limited circle of actors	
	Support of top management	Scenario analysis is initiated by top management (top-down)	Strategic planning department is driver of scenario process	Top management has to be convinced			
	Willingness of employees to participate	Willingness to participate in workshops	Willingness to participate in interviews	Willingness to answer a questionnaire	Willingness to critically review ex ante material	No willingness to participate	

	Time resources for workshops	Up to one day	1-2 day	3 days			
	Time resources for the analysis	Up to three months	3-6 months	6-12 months			
	Financial resources	Budget for studies, reports and literature	Budget allows participation of a specialized consulting firm	Budget allows own software	Budget allows no participation of a specialized consulting firm	No budget for studies, reports and literature	No budget for software support
Goal	**Goal of the analysis**	Development of implications for concrete investment decisions	Check for robustness for business plans	Testing a strategy in the light of the scenarios	Network development, communication	Development of implications for strategic alignment (market, new application fields)	Validation and elicitation of requirements
	Target group	Decision-maker/management	Public/dialogue with customers	R&D department	Banks, venture capital providers	Politics	
	Goal-directedness of scenarios	Descriptive scenarios	Normative scenarios				
	Vantage point	Explorative	Anticipatory				
	Scenario field	System scenarios	Environment scenarios				
	Communication/coordination	Consensus, development of a common language	Bringing different hierarchical level or departments together	Integration of external persons (e.g. customers, suppliers)	Network development		

Scenario process	**Nature of scenarios**	Situation scenarios	Process scenarios				
	Number of future horizons	Single stage	Multi stage				
	Number of future projections per key factor	Limited	Open	Constant number			
	Assignment of probabilities to future projections	Assignment of probabilities to projections	No assignment of probabilities for projections				
	Number of scenarios	Constant number	Variable number				
	Form of expert opinion integration	Interviews with selected experts	Application of existing studies	Delphi survey			
	Composition of core team	Internal	External	Mixed			
	Number of participants in analysis	Less than 5 participants	5-10 participants	10-20 participants	20-30 participants	More than 30 participants	
Scenario transfer	**Number of scenarios that are relevant for planning**	Focused strategy (one scenario)	Partly robust strategy (several scenarios)	Future robust strategy (all scenarios)	General recommended actions		

	Trend monitoring	Results of the trend monitoring are incorporated in scenario process	Development of trend monitoring is planned	No trend monitoring			

Source: Mietzner 2009.

The range of goals that scenarios can address is quite broad as was elaborated in the second chapter. This study addresses the problem of systems embedded in changing environments and resulting changes in requirements. Its goal is to test the robustness of the current material in the light of future developments and to give strategic implications. The scenarios should also work as requirements analysis tool with new requirements to be found. Nevertheless, a learning effect in the organization about future developments should be achieved within the process and the scenarios are ought to function as a communication tool for different departments (van der Heijden, 2009).

Fundamental decisions concerning characteristics of the scenario that have to be made for a scenario project include the goal-directedness of scenarios, their nature, their vantage point, the problem statement and the scenario field. The goal-directedness of a scenario focuses on how normative a scenario is. It is distinguished between descriptive scenarios that explore possible futures without positive or negative value judgments being made, and normative scenarios that describe preferable futures, which means that they are directed towards certain desirable ends, or they involve positive and negative value judgments concerning the events or circumstances described (van Notten et al., 2003; Wright, Gutwirth, Friedewald, Vildjiounaite, & Punie, 2010).

The nature of the scenario can either be a situation or a process. Process scenarios describe the path of development to a particular end-state. Situation scenarios describe the end-state of a particular path of development but only implicitly address the processes that result in that end-state.

Characteristic for a scenario is the vantage point from which it is developed. With this characteristic a distinction is made between what the literature describes as exploratory or forecasting scenarios, and prescriptive, anticipatory or backcasting scenarios (Godet & Roubelat, 1996). Explorative proceed from a given set of circumstances and attempt to draw conclusions about possible effects - i.e. they describe a future from a given present. Anticipatory scenarios proceed from a defined future set of circumstances (effect) and attempt to draw conclusions about the possible causes that could lead to such a future (Wright et al., 2010).

With regard to the underlying problem statement it is differentiated between decision projects or orientation projects. In decision projects scenarios are used to choose among various alternative the one that makes the best contribution to target compliance. Decision projects directly affect guiding principles and strategies. In orientation projects scenarios do not serve to make a decision between various choices of actions but to the determination of general decision behavior. Orientation scenarios have an indirect influence on guiding principles and strategies. The scenario field is divided into environment oriented, steering oriented and system oriented scenarios. Environment oriented scenarios consist only of non-steerable environment factors. With such scenarios organizations try to anticipate possible general conditions for the future to identify chances and risks. Steering oriented scenarios are only built with factors that can be influenced by the organization. System oriented scenarios are a combination of the other two and consist factors of the environment and factors influenceable by the organization (Richter, 2010).

The study performed here uses descriptive scenarios by exploring possible futures. A normative scenario would not be useful in this case as different departments for specific parts in the interior would have different preferable futures. Furthermore is a normative scenario not of great use when it cannot be achieved with the existing possibilities. The scenarios are a snapshot of the future – situation scenarios. They implicitly address some of the processes that result in that state, however, a comprehensive explanation of all processes would go beyond the limits of this study. This scenario analysis is utilized to draw conclusions about various developments concerning the automobile interior identified at the current point in time and conclusions about the possible effects are to be drawn, an explorative process. The underlying problem in this study is an orientation problem because the scenarios do not serve to make a decision between different choices of actions. Moreover is the scenario field environment oriented because macro developments at such a high level are eventually barely influenceable by the applicant.

APPENDIX C: STUDIES ANALYZED

Table 5: Studies analyzed

No.	Name of the study	Year	Autor	Editor/publisher	Type of study	Aim
1	Automotive landscape 2025 - Opportunities and challenges ahead	2011	Kalmbach, R.; Bernhart, W.; Grosse Kleimann, P.; Hoffmann. M.	Roland Berger	Trend study + scenario analysis	Identification of megatrends and their implications for the automotive industry in 2025 by the identification of common success factors in three scenarios
2	Die Innovationen der globalen Automobilkonzerne	2011	Bratzel, S.; Tellermann, R.	Center of Automotive Management	Trend study	Analysis of future trends and innovation profiles of the 20 most important manufacturers
3	A new era, accelerating towards 2020 - An automotive industry transformed	2009		Deloitte	Trend study	Identification of structural changes and major customer, technology, and people trends expected to transform the industry over the next decade
4	Future of urban mobility - Towards networked, multimodal cities of 2050	2011	Lerner, W.	Arthur D. Little future lab	Trend study	Assessment of mobility maturity and performance as well as new mobility concepts in 66 cities worldwide
5	Unser Auto von morgen	2011	Weiss, T.	AutoScout24	Consumer research	Identification of consumer needs in the car for the next 25 years
6	Zukunft der deutschen Automobilindustrie - Herausforderungen und Perspektiven für den Strukturwandel im Automobilsektor	2010	Barthel, Klaus; Böhler-Baedeker, Susanne; Bormann, René; Dispan, Jürgen; Fink, P.; Koska, T.; Meißner, H.-R.; Pronold, F.	Friedrich-Ebert-Stiftung	Outlook	Problems and strategies, but also chances and risks of political, social, ecological, technological and economic developments in Germany
7	Navigating in the new consumer realities	2011	Roche, C.; Ducasse, P.; Liao, C.	Boston Consulting Group	Consumer research	Analysis of five consumer trends
8	Szenarien der Mobilitätsentwicklung unter Berücksichtigung von Siedlungsstrukturen bis 2050	2006		Bundesministerium für Verkehr, Bau und Stadtentwicklung	Scenario analysis	Alternative scenarios for the developments in traffic
9	Zukunft von Mobilität und Verkehr - Auswertungen wissenschaftlicher Grunddaten, Erwartungen und abgeleiteter Perspektiven des Verkehrswesens in Deutschland	2010	Ahrens, G.-A.; Kabitzke, U.	Bundesministerium für Verkehr, Bau und Stadtentwicklung, Technische Universität Dresden	Scenario analysis	Alternative scenarios through global megatrends and developments for mobility and traffic
10	CO2-Emissionsminderung im Verkehr in Deutschland - Mögliche Maßnahmen und ihre	2010	Rodt, S.; Georgi,B.; Huckestein, B.; Mönch,	Umweltbundesamt	Scenario analysis	Trend scenario for different action measures till 2030

	Minderungspotenziale		L.; Herbener, R.; Jahn, H.; Koppe, K.; Lindmaier, J.			
11	Continental-Mobilitätsstudie	2011	Sommer, K.	Continental	Consumer research	Analysis of the relevance of e-mobility in our future everyday mobility
12	Mobility 3.0 - Hoffnungsträger oder Millionengrab	2011	Deeg, M.; Görner, A.; Greiner, O.; Petschnig, M.; Schneider, C.	Esch, F.-R.; Gleich, R.; Griner, O.	Trend study	Analysis of the future of mobility with not only technological, but also ecological, economical, social and political developments till 2020/30
13	Energieszenarien für ein Energiekonzept der Bundesregierung	2010	Schlesinger, M.; Lindenberger, D.; Lutz, C. et al.	Bundesministerium für Wirtschaft und Technologie, Prognos AG, EWI, GWS	Scenario analysis	Alternative scenarios for the future energy supply and emissions in Germany in the years 2020/30/40/50
14	Marktmodell Elektromobilität, Bericht Teil 1 Ansatz und Ergebnisse	2011		ESMT, Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit	Scenario analysis	Simulation model for the development of e-mobility as building block of a post-fossil mobility culture in Germany
15	Business redefined - A look at the global trends that are changing the world of business	2010	Pearson, I.; Forer, G.; Hyek, P. A.	Ernst & Young	Trend study	Analysis of the six most influential trends that will redefine business success and key questions that business leaders should be asking themselves right now
16	Mobilität in Ballungsräumen	2009	Hinkeldein, D.	Deutsches Zentrum für Luft- und Raumfahrt	Literature review	Comprehensive overview and comparison of the results of 173 publications in the fields of mobility development
17	Politikszenarien V – auf dem Weg zum Strukturwandel, Treibhausgas-Emissionsszenarien bis zum Jahr 2030	2010	Gores, S.; , Harthan, R. O.; Matthes, F. C.; Mohr, L.; Penninger, G.; Hansen, P. Markewitz, P. et al.	Hansen, P.; Matthes, F. C.	Scenario analysis	Two alternative scenarios in the year 2030 analyzing different climate protection effects
18	Zukunft der Mobilität - Szenarien für das Jahr 2030	2010		Institut für Mobilitätsforschung	Scenario analysis	Three scenarios of future development in mobility in Germany till 2030
19	Megatrends - Update	2012		z_punkt	Trend study	20 global trends as powerful factors which shape future markets
20	The future of the car	2008	Kaiser, O. S.; Eickenbusch, H.; Grimm, V.; Zweck, A.	Association of German Engineers (VDI)	Trend study	Analysis of technologial trends in essential vehicle components to 2020 and presentation of two concept cars
21	Jugend und Automobil - Eine empirische Studie zu Einstellungen und Verhaltensmustern von 18 bis 25-Jährigen in Deutschland	2010	Bratzel, S.; Lehmann, L.	FHDW Center of Automotive	Customer analysis	Automobile preferences and buying patterns of the young generation in Germany
22	Megatrends 2030 - Unternehmerische Entscheidungen in spannenden Zeiten	2011	Brunke, B.	Roland Berger	Trend study	Seven chances and challanges for organizations concerning megatrends in a volatile world
23	Tensions from the two-speed recovery -	2011		International Monetary	Outlook	Analysis and projections of economic

	Unemployment, commodities, and capital flows			Fund		developments and policies in the IMF's member countries, of developments in international financial markets, and of the global economic system.
24	Weissbuch - Fahrplan zu einem einheitlichen europäischen Verkehrsraum – Hin zu einem wettbewerbsorientierten und ressourcenschonenden Verkehrssystem	2011		Europäische Kommission	Outlook	Vision for a sustainable traffic area in Europe and the strategy to achieve it
25	Technologische und wirtschaftliche Perspektiven Deutschlands durch die Konvergenz der elektronischen Medien	2011	Botthof, A.; Domröse, W.; Groß, W. et al.	VDI/VDE/IT, Bundesministerium für Wirtschaft und Technologie	Trend study + scenario analysis	Identification of promising future markets and their characteristics, one of them being mobility amongst other methods based on previous scenario analyses
26	Mehr Wohlstand – weniger Ressourcen Instrumente für mehr Ressourceneffizienz in Wirtschaft und Gesellschaft	2011	Reuscher, G.; Ploetz, C.; Yemets, Y.; Zweck, A.	VDI	Outlook	Analysis of potential and impact of different instruments for more resource efficiency in mobility, nutrition, ICT and living
27	Future technologies - Update	2011	Hoffknecht, A.; Zweck, A.	VDI	Outlook	Overview of new technologies and developments with a high innovation potential with a focus on resource efficiency
28	Aktuelle Technologieprognosen im internationalen Vergleich	2006	Holtmannspötter,D.; Rijkers-Defrasne, S.; Glauner, C.; Korte, S.; Zweck, A.	VDI	Trend study	Meta analysis of technology prognoses for an overview of future technology development and the derivation of national strengths and characteristics (also in the field of materials), time horizon 2030
29	Elektromobilität	2011	Kaiser, O. S.; Meyer, S.; Schippl, J.	VDI	Outlook	Overview of technological, socio-economic and ecological developments concerning e-mobility to derive open questions
30	Biomasse – Rohstoff der Zukunft für die chemische Industrie	2011	Grimm, V.; Braun, M.; Teichert, O.; Zweck, A.	VDI	Outlook	Analysis of the status and perspectives of biomass and ist fields of application
31	UMBReLA Umweltbilanzen Elektromobilität	2011	Helms, H.; Jöhrens, J.; Hanusch, J.; Höpfner, U.; Lambrecht, U.; Pehnt, M.	Institut für Energie und Umweltforschung; Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit	Outlook	Environmental balance of e-mobility with the analysis of challenges and the development of perspectives
32	Transport Outlook 2009 Globalisation, Crisis and Transport	2009		International Transport Forum, OECD	Scenario analysis	Scenario analysis of the relation between expected GDP evolution and the demand for road transport
33	The world in 2025 - Rising Asia and socio-ecological transition	2009	Baer, J.-M.	European Commission	Trend study	Analysis of trends concerning the rise of Asia and resulting tensions and major transitions
34	The Outlook for Energy - A view to 2030	2008		Exxon Mobil Corporation	Outlook	Modelling of energy supply and demand till 2030
35	The great eight - Trillion-dollar growth trends to 2020	2011		Bain & Company	Trend study	Analysis of the eight most important global trends and their opportunities for businesses

36	The global technology revolution - Bio/nano/materials trends and their synergies with information technology by 2015	2001	Antón, P. S.; Silberglitt, R.; Schneider, J.	National Defense Research Institute; National Intelligence Council	Trend study	Projections of the development of bio, nano and materials to 2015
37	Optionen für Deutschlands Automobilindustrie	2010		Technomar	Scenario analysis	Scenario analysis to derive a strategy to push the diffusion of e-mobility
38	Technology Outlook 2020	2011		DNV	Trend study + scenario analysis	Analysis of future technologies in four main areas: shipping, fossil energy, renewable and nuclear energy, and power systems with the most important global trends impacting on these technologies
39	Globalisation of the automotive industry: main features and trends	2009	Sturgeon, T. J.; Memedovic, O.; Van Biesebroeck, J.; Gereffi, G.		Trend study	Identification of several important trends in the global automotive industry e.g. glocalization
40	Materialtrends - Designing with Materials	2008	Peters, S.		Trend study	Analysis of material trends and current developments
41	Smart Materials: Technologies and Global Markets	2011	McWilliams, A.	BCC Research	Outlook	Overview of smart materials and their diffusion forecasts till 2016
42	Shell PKW-Szenarien bis 2030 - Fakten, Trends und Handlungsoptionen für nachhaltige Auto-Mobilität	2009		Shell	Scenario analysis	Development of mobility scenarios to examine how sustainable auto-mobility will develop in the coming years, measured by energy consumption and CO2 emissions
43	Scenarios for the Future of Technology and International Development	2010		The Rockefeller Foundation; Global Business Network	Scenario analysis	Analysis of technologies that improve the capacity of individuals, communities, and systems to respond to major changes 15-20 years from now
44	Prospects and opportunities of information and communication technologies (ICT) and media	2009	Gerneth, M.; Kessel, T.; Wolf, M.	Münchner Kreis, European Center for Information and Communication Technologies, Deutsche Telekom AG, TNS	Delphi study	Discussion about the significance and future development of information and communication technologies (ICT) and media in 2030
45	China takes the lead in electric vehicles deployment	2012		ENERDATA; Polinares	Scenario analysis	'What-if' scenario that supposes a very optimistic 'breakthrough' type growth of electric vehicles in China with consequences on recource and consumer markets
46	Passive safety technologies, trends and forecasts to 2015	2011	Murphy, M.	Automotive World	Trend study	Trends in safety technologies, their market drivers and barriers
47	Global trends 2025: a transformed world	2008		National Defense Research Institute; National Intelligence Council	Scenario analysis	Identification of key trends that significantly shape the world and scenarios that stimulate strategic thinking

48	Nanotechnologien im Automobil	2006	Werner, M.; Kohly, W.; Simic, M.; Forchert, C. E.; Rumsch, W. C.; Klimpel, V.; Ditfe, J.	Hessisches Ministerium für Wirtschaft, Verkehr und Landesentwicklung	Trend study	Overview of possible application areas of nanotechnology in automobiles in the future
49	Mobilität für morgen - Verkehrspolitische Leitlinien des ACE	2008		Auto Club Europa	Outlook	Transport political guidelines to secure a social, sustainable and efficient future mobility
50	Mobility of the future	2012	Cornet, A.; Mohr, D.; Weig, F.; Zerlin, B.; Hein, A.-P.	McKinsey&Company	Trend study	Overview of global trends that shape the autoomobile industry in the future and the opportunities they hold for automotive OEMs
51	Klimaneutral mobil im 21. Jahrhundert: Multimodalität, neue Fahrzuegkonzepte und mehr	2012		Klima- und Energiefonds; Bundesministerium für Verkehr, Innovation und Technologie, FFG	Outlook	Overview of projects concerning climate neutral mobility in the future
52	Eine integrative Szenarienanalyse der langfristigen Ölpreisentwicklung	2009	Kesicki, F.; Remme, U.; Blesl, M.; Fahl, U.		Scenario analysis	Modell displaying the oil price in 2030 in different scenarios
53	BRICs and beyond	2007	O'Neill, J.	Goldman Sachs Global Economics Group	Outlook	Analysis of the BRICs and other new markets and their potential in the future till 2050
54	Vision für nachhaltigen Verkehr in Deutschland	2011	Schade, W.; Peters, A.; Doll, C.; Klug, S.; Köhler, J.; Krail, M.	Fraunhofer ISI	Scenario analysis	Identification of trends and their influence to create a vision for sustainable mobility in 2050
55	Giving the beat - Von der Mindset-Forschung zur Trendforschung	2002		MTV	Consumer research	Different consumer mindets of young people between 14 and 29 and the trends they find important.
56	Leisure time II	2011		Viacom, MTV	Consumer research	Interests and attitudes of young people between 14 and 29, segmentation into five mindsets
57	Well being	2004		MTV, Nickelodeon	Consumer research	The impact of globalization on the real lives of young people around the world
58	Youngminder	2005		MTV	Consumer research	Consumer research on the "youngminders", people between 30 and 49 about leisure time, media and brands
59	Mobilität 2020 - Perspektiven für den Verkehr von morgen	2006	Beckmann, K.; Boßmeyer, H. J. et al.	Acatech; Fraunhofer IRB	Scenario analysis	Scenario analysis for a traffic scenario in the year 2020 in Germany and the derivation of aims and measures to achieve the scenario
60	Ultra Materials - Innovative Materialien verändern die Welt	2007	Beylerian, G. M.; Dent, A.		Trend study	Overview of more than 400 of the most innovative materials from Material Connexion's material library, examination how they interact with the design industry and material innovations
61	The future of the global economy to 2030	2008	Keith, A.; O'Brian, R.; Prest, M.	Outsights	Scenario analysis	Scenario analysis that explores the possible dawn of a new era, shaped by five key drivers of change: Sustainability, People, Technology, Political models and Economic outcomes to create four scenarios

62	Global scenarios 2000 - 2050	2000	Daivs, G.; Flowers, B. S.; Golüke, U.; Heinzen, B.; Khong, C.; Länge, K.; McKay, D.; Wouters, A.	3M Company; IBM; Novartis; Shell et al.	Scenario analysis	Three scenarios that explore possible responses to the challenge of sustainable development. These responses arise from habitual patterns of thinking that form who we are, whether or not we are conscious of them

APPENDIX D: INTERVIEW GUIDELINE FOR THE REQUIREMENTS ANALYSIS

Figure 6: Interview guideline for the requirements analysis

Interview Guideline Requirements Analysis

General questions

- Which component or group of components are you responsible for?
- What materials do they mainly consist of?
- With which technologies are they manufactured?

Questions after each scenario

- Which factors or events have the strongest influence on your choice of material?
- Which factors or events have no influence on your choice of material?
- Which requirements does the scenario impose regarding the material in the interior?
- Can you prioritize those requirements?
- Can the currently used material entirely fulfill those requirements? (Why not?)
- Can you name other industries that are subject to the same or similar requirements, where you would search for solutions to fulfill those requirements?

Control question

- Are there other macro factors not displayed in the scenarios that might have a strong influence on your material in the future?

APPENDIX E: SOFTWARE USED IN THE INTERVIEWS TO FILL IN THE MATRIX

Figure 7: Software used in the interviews to fill in the matrix

Due to confidentiality this part of the thesis has been excluded.

APPENDIX F: COLLECTED INFLUENCING FACTORS

Table 6: Collected influencing factors

Due to confidentiality this part of the thesis has been excluded.

APPENDIX G: DEVELOPMENT OF PATENT APPLICATIONS

Figure 8: Development of patent applications

Due to confidentiality this part of the thesis has been excluded.

APPENDIX H: INFLUENCE MATRIX

Figure 9: Influence matrix

Due to confidentiality this part of the thesis has been excluded.

APPENDIX I: PROJECTIONS

Due to confidentiality this part of the thesis has been excluded.

APPENDIX J: CONSISTENCY MATRIX

Figure 10: Consistency matrix

Due to confidentiality this part of the thesis has been excluded.

APPENDIX K: SCENARIOS

Due to confidentiality this part of the thesis has been excluded.

APPENDIX L: MATERIAL REQUIREMENTS

Due to confidentiality this part of the thesis has been excluded.

APPENDIX M: CURRENT MATERIAL CHARACTERISTICS AND GAPS

Due to confidentiality this part of the thesis has been excluded.

APPENDIX N: MATERIAL SOLUTIONS IN OTHER INDUSTRIES

Table 7: Suggestions for material solutions in other industries

Due to confidentiality this part of the thesis has been excluded.

APPENDIX O: INVENTION DISCLOSURE

Due to confidentiality this part of the thesis has been excluded.

PUBLICATION BIBLIOGRAPHY

Acatech; Fraunhofer IRB. (2008). *Materialwissenschaft und Werkstofftechnik in Deutschland: Empfehlungen zu Profilierung, Lehre und Forschung*. Stuttgart: Fraunhofer-IRB-Verlag.

Alexander, I. F. (2004). Introduction: Scenarios in system development. In I. F. Alexander & N. Maiden (Eds.), *Scenarios, stories, use cases. Through the systems development life-cycle* (pp. 3–24). Chichester: Wiley.

Alexander, I. F., & Maiden, N. (Eds.). (2004). *Scenarios, stories, use cases: Through the systems development life-cycle*. Chichester: Wiley. Retrieved from http://site.ebrary.com/lib/alltitles/docDetail.action?docID=10307855

Amancio-Filho, S., & dos Santos, J. (2009). Joining of polymers and polymer-metal hybrid structures: Recent developments and trends. *Polymer Engineering & Science*, *49*(8), 1461–1476.

America, P., Hamme, D., Ionita, M. T., Obbink, H., & Rommes, E. (2004). Scenario-based decision making for architectural variability in product families. *Software Process Improvements and Practice*, *3154*, 171–187.

Ansoff, H. I., Avner, J., Brandenburg, R. G., Partner, F. E., & Radosevich, R. (1970). Does planning pay? The effect of planning on success of acquisitions in American firms. L. *Long Range Planning*, *3*(2), 2–7.

Antón, P. S., Silberglitt, R. S., & Schneider, J. (2001). *The global technology revolution: Bio/nano/materials trends and their synergies with information technology by 2015*. Santa Monica, CA: RAND.

Bain & Company. (2011). *The great eight: trillion-dollar growth trends to 2020*. Retrieved from http://www.bain.com/Images/BAIN_BRIEF_8MacroTrends.pdf

Balderjahn, I. (2004). *Nachhaltiges Marketing-Management: Möglichkeiten einer umwelt- und sozialverträglichen Unternehmenspolitik*. *Forum Marketing & Management: Vol. 5*. Stuttgart: Lucius & Lucius.

Baraldi, E., Gressetvold, E., & Harrison, D. (2012). Resource interaction in inter-organizational networks: Foundations, comparison, and a research agenda. *Journal of Business Research,* 65, 266-276.

Barthel, K., Böhler-Baedeker, S., Bormann, R., Dispan, J., Fink, P., Koska, T. (2010). *Zukunft der deutschen Automobilindustrie: Herausforderungen und Perspektiven für den Strukturwandel im Automobilsektor*. *Expertisen und Dokumentationen zur Wirtschafts- und Sozialpolitik*. Berlin.

Becker, P. (2002). *Corporate foresight in Europe: a first overview*. Retrieved from ftp://ftp.cordis.europa.eu/pub/foresight/docs/st_corporate_foresight_040109.pdf

Berg, B. L. (2004). *Qualitative research methods for the social sciences* (5th ed.). Boston: Pearson.

Bergholz, R., Timm, K., & Weisser, H. (November 3), Volkswagen AG US 6151539 A. USA.

Bishop, P., Hines, A., & Collins, T. (2007). The current state of scenario development: an overview of techniques. *Foresight*, *9*(1), 5–25.

Blackburn, R. (2009). *Car interiors of the future*. Retrieved from http://news.drive.com.au/drive/motor-news/car-interiors-of-the-future-20091016-h0c9.html

Bogner, A., & Menz, W. (2002). Das theoriegenerierende Experteninterview: Erkenntnisinteresse, Wissensformen, Interaktion. In A. Bogner, B. Littig, & W. Menz (Eds.), *Das Experteninterview. Theorie, Methode, Anwendung* (pp. 33–70). Opladen: Leske und Budrich.

Bradfield, R., Wright, G., Burt, G., Cairns, G., & van der Heijden, K. (2005). The origins and evolution of scenario techniques in long range business planning. *Futures*, *37*(8), 795–812.

Bratzel, S. & Tellermann, R. (2011). *Die Innovationen der globalen Automobilkonzerne: Eine Analyse der Zukunftstrends und Innovationsprofile der 20 bedeutendsten Hersteller,* Center of Automotive Management.

Braun, A., Glauner, C., & Zweck, A. (2005). *Einführung in die Praxis der "Regionalen Vorausschau": Hintergründe und Methoden,* Zukünftige Technologien Consulting, ZTC Working Paper 2, Düsseldorf.

Brunke, B. (2011). *Megatrends 2030 - Unternehmerische Entscheidungen in spannenden Zeiten,* Roland Berger Strategy Consultants, Weimar.

Bui, Y. N. (2009). *How to write a master's thesis*. Los Angeles, Calif: Sage.

Bundesministerium der Justiz (2009). Gesetz *zur Einsparung von Energie in Gebäuden,* EnEG 28.03.2009. Retrieved from http://www.gesetze-im-internet.de/eneg/BJNR018730976.html

Bundesministerium der Justiz (2012). *Gesetz über die friedliche Verwendung der Kernenergie und den Schutz gegen ihre Gefahren (Atomgesetz)*, Atg 24.02.2012. Retrieved from http://www.gesetze-im-internet.de/atg/BJNR008140959.html#BJNR008140959BJNG000100326

Burmeister, K. & Neef, A. (2008). *Die 20 wichtigsten Megatrends*. Retrieved from http://www.z-punkt.de/fileadmin/be_user/D_Publikationen/D_Arbeitspapiere/Die_20_wichtigsten_Megatrends_x.pdf

Burmeister, K., Neef, A., & Beyers, B. (2004). *Corporate Foresight: Unternehmen gestalten Zukunft* (1st ed.). *Murmann Business & Management*. Hamburg: Murmann.

Bush, D. (2004). Alternative world scenarios to assess requirement stability. In I. F. Alexander & N. Maiden (Eds.), *Scenarios, stories, use cases. Through the systems development life-cycle* (pp. 103–117). Chichester: Wiley.

Chandler, A. D. (1962). *Strategy and structure: Chapters in the history of the industrial enterprise*. Cambridge, Mass: M.I.T. Press.

Cox, R. W. (1994). Global restructuring: Making sense of the changing international political economy. In R. Stubbs & R. D. Goeffrey (Eds.), *Political economy and the changing global order* (pp. 45–59). New York: St. Martin's Press.

Courtney, H., Kirkland, J., & Viguerie, P. (1997). Strategy Under Uncertainty. *Harvard Business Review*, *75*(6), 67–79.

Creswell, J. W. (2003). *Research design: Qualitative, quantitative, and mixed method approaches* (2nd ed.). Thousand Oaks, Calif: SAGE Publications.

Cuhls, K. (2003). From forecasting to foresight processes: New participative foresight activities in Germany. *Journal of Forecasting*, *22*(2-3), 93–111.

Drew, S. A. W. (2006). Building technology foresight: using scenarios to embrace innovation. *European Journal of Innovation Management*, *9*(3), 241–257.

Daimler AG. (2012). *Strategie Portal.* Daimler AG Intranet.

Davies, G. (2012). Materials for Automobile Bodies (2nd ed.). Burlington: Elsevier Science. Retrieved from http://www.gbv.eblib.com/patron/FullRecord.aspx?p=888998

de Jouvenel, H. (2000). A Brief Methodological Guide to Scenario Building. *Technological Forecasting and Social Change*, *65*(1), 37–48.

Deeg, M., Görner, A., Greiner, O., Petschnig. M., & Schneider, C. (2011). *Mobility 3.0: Hoffnungsträger oder Milliardengrab?,* Automotive Institute for Management (AIM), EBS Business School.

Deloitte. (2009a). *A new era: Accelerating toward 2020 - An automotive industry transformed.*

Deloitte. (2009b). *Scenario planning in life science R&D: Planning for uncertainty*. Retrieved from http://www.deloitte.com/assets/Dcom-UnitedStates/Local%20Assets/ Documents/us_lshc_ ScenarioPlanning_100909.pdf

Denscombe, M. (1998). *The good research guide for small-scale social research projects*, Buckingham: Open University Press.

DNV. (2011). *Technology Outlook 2020*. Retrieved from http://production.presstogo.com/ fileroot/gallery/DNV/files/preview/9ec457bc750b4df9e040007f0100061c/9ec457bc75094df9e040 007f0100061c.pdf

Economist Intelligence Unit. (2011). The future of healthcare in Europe. *The Economist*, 3.

Ellen Macarthur Foundation. (2011). *Towards the circular economy: Economic and business rationale for an accelerated transition.* Retrieved from http://www.ellenmacarthurfoundation.org/ circular-economy

Enerdata. (2012). *Case 5: China takes the lead in electric vehicles deployment,* Polinares Working Paper 49, European Commission; Seventh Framework Programme.

ESMT Berlin, Bundesministerium für Umwelt Naturschutz und Reaktorsicherheit (2011). *Marktmodell Elektromobilität - Bericht Teil 1 Ansatz und Ergebnisse*. Retrieved from http://mmem.eu/assets/report/ESMT-Marktmodell-Elektromobilitaet-Bericht.pdf

European Centre for the Development of Vocational Training. (2010). *Skills supply and demand in Europe: Medium-term forecast up to 2020*. Luxembourg: Publ. Off. of the European Union.

European Union: European Parliament (2009). *Directive 2009/28/EC of the European Parliament and the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC.* Retrieved from http://eur-lex.europa.eu/LexUriServ/LexUriServ.do ?uri=CELEX: 32009L0028:en:NOT

Fink, A., & Siebe, A. (2006). *Handbuch Zukunftsmanagement: Werkzeuge der strategischen Planung und Früherkennung*. Frankfurt am Main: Campus.

Fink, A., Schlake, O., & Siebe, A. (2002). *Erfolg durch Szenario-Management: Prinzip und Werkzeuge der strategischen Vorausschau* (2nd ed.). Frankfurt/Main: Campus-Verlag.

Fraunhofer-Institut für System- und Innovationsforschung - ISI-. (2010). *Energietechnologien 2050 - Schwerpunkte für Forschung und Entwicklung*. Stuttgart: Fraunhofer-Verlag.

Fuchs, E., Field, F., Roth, R., & Kirchain, R. (2008). Strategic materials selection in the automobile body: Economic opportunities for polymer composite design. *Composites Science and Technology*, *68*(9), 1989–2002.

Gaßner, R., & Steinmüller, K. (2006). Narrative normative Szenarien in der Praxis. In F. E. P. Wilms (Ed.), *Szenariotechnik. Vom Umgang mit der Zukunft* (1st ed., pp. 133–144). Bern: Haupt Verlag.

Gausemeier, J. (Ed.) 2009. *Vorausschau und Technologieplanung,* 5. Symposium für Vorausschau und Technologieplanung, Berlin-Brandenburgische Akademie der Wissenschaften, Heinz Nixdorf Institut.

Gausemeier, J., Fink, A., & Schlake, O. (1996). *Szenario-Management: Planen und Führen mit Szenarien* (2nd ed.). München: Hanser Fachbuchverlag.

Gausemeier, J., Fink, A., & Schlake, O. (1998). Scenario management: an approach to develop future potentials. *Technological Forecasting and Social Change*, *59*(2), 111–130.

Gausemeier, J., Plass, C., & Wenzelmann, C. (2009). *Zukunftsorientierte Unternehmensgestaltung: Strategien, Geschäftsprozesse und IT-Systeme für die Produktion von morgen*. München: Hanser.

Geschka, H., & Hammer, R. (1983). Die Szenario-Technik in der strategischen Unternehmens-planung. In A. Töpfer, H. Afheldt, & M. Andreä (Eds.), *Praxis der strategischen Unternehmensplanung* (pp. 125–170). Frankfurt a. M.

Ghassemieh, E. (2011). Materials in Automotive Application, State of the Art and Prospects. In M. Chiaberge (Ed.), *New Trends and Developments in Automotive Industry.* InTech.

Gläser, J., & Laudel, G. (2010). *Experteninterviews und qualitative Inhaltsanalyse: Als Instrumente rekonstruierender Untersuchungen* (4th ed.). Wiesbaden: VS Verlag für Sozialwiss.

Glasscock, D. (2011). *Wards Auto Industry Study.* WardsAuto; DuPont Automotive.

Godet, M. (1987). *Scenarios and strategic planning*. London: Butterworth.

Godet, M. (2001). *Creating futures: Scenario planning as a strategic management tool*. London: Economica.

Godet, M., & Roubelat, F. (1996). Creating the Future: The Use and Misuse of Scenarios. *Long Range Planning*, *29*(2), 164–171.

Goede, M., Stehlin, M., Rafflenbeul, L., Kopp, G., & Beeh, E. (2009). Super Light Car—lightweight construction thanks to a multi-material design and function integration. *European Transport Research Review*, *1*(1), 5–10

Goetheer, A., Heijs, J., & Oelen, J. P. (2010). *Challenging futures "How can scenarios help to cope with uncertainties?": A handbook for applying the scenario analysis method in innovation agencies*. Retrieved from http://www.taftie.org/sites/default/files/docs/PDF/ Agency%202020%20 Challenging%20futures.pdf

Goldman Sachs Global Economic Group. (2007). *BRICs and beyond,* Goldman Sachs.

Google. (2011). *The impact of clean energy innnovation: Examining the impact of clean energy innovation on the United States energy system and economy,* Google.

Gorden, R. L. (1975). *Interviewing. Strategies, techniques and tactics*. Homewood, Illinois: The Dorsey Press.

Gordon, T. J. (1994). *Integration of forecasting methods and the frontiers of future research*. Washington, D.C.: Futures Research Methodology (Version 20) AC/UNU Millenium Project.

Gores, S., Harthan, R. O., Matthes, F. C., Mohr, L., Penninger, G., Hansen, P. M. P., … (2010). *Politikszenarien für den Klimaschutz V - auf dem Weg zum Strukturwandel, Treibhausgas-Emissionsszenarien bis zum Jahr 2030.* (Hansen, P., & Matthes, F. C., Eds.). Jülich: Forschungszentrum Jülich.

Gottschalk, L. A. (1995). *Content analysis of verbal behavior: New findings and clinical applications*. Hillsdale, N.J: Lawrence Erlbaum Associates.

Götze, U. (1991). *Szenario-Technik in der strategischen Unternehmensplanung*. Univ.-Diss. Wiesbaden: Deutscher Universitäts Verlag.

Graf, H. G. (2000). *Globale Szenarien: Megatrends im weltweiten Kräftespiel*. Frankfurt am Main: Frankfurter Allg. Ztg. Verl.-Ber. Buch.

Greeuw, S. C. H., van Asselt. M., & Grosskurth, J. (2000). *Cloudy crystal balls: An assessment of recent European and global scenario studies and models: experts' corner report*. *Environmental issues: Vol. 17*. Luxembourg: Office for Official Publications of the European Communities.

Haaker, T., & van Buuren, R. (Eds.) 2005. *Futures scenarios approach for aiding the design of innovative systems*. Retrieved from http://www.itseurope.org/ITS%20CONF/porto05/abstracts/Haaker_van%20Buuren.pdf

Hakansson, H., & Waluszewski, A. (2002). *Managing technological development – IKEA, the environment and technology*. London. Routledge.

Halldórsson, Á., & Kovács, G. (2010). The sustainable agenda and energy efficiency: Logistics solutions and supply chains in times of climate change. *International Journal of Physical Distribution & Logistics Management*, *40*(1-2), 5–13.

Hanley, M., Henning, J., Valsan, A., & Nassif, A. (2011). *Eight mega trends shaping the global light vehicle industry.*

Hay Group. (2011). *Individualization and value pluralism: Leadership 2030,* Hay Group.

Henning, K., Hees, F., & Hansen, A. (2009). Dynaxibility for innovation — global trends in the field of "working, learning, developing skills". In L. Gómez Chova, D. Martí Belenguer, & I. Candel Torres (Eds.), *ICERI 2009. Abstracts cd.* Valencia: International Association of Technology, Education and Development.

Heuss, R. & Müller, N. (2012). *CO2-Regulierung sorgt bis 2030 für dreistelliges Milliardenwachstum im Leichtbau*, McKinsey&Company. Retrieved from http://www.mckinsey.de/html/presse/2012/20120105_PM-Leichtbau.asp

Hyek, P. A. (2010). Riding the wave of technological innovation. In Ernst & Young (Ed.), *Business redefined. A look at the global trends that are changing the world of business* (p. 25).

Institut für Mobilitätsforschung. (2005). *Zukunft der Mobilität – Szenarien für das Jahr 2025,* Berlin.

Institut für Mobilitätsforschung. (2010). *Zukunft der Mobilität - Szenarien für das Jahr 2030,* Berlin.

International Council for Science. (2011). *ICSU Foresight Analysis Report 1: International science in 2031 - exploratory scenarios*. Retrieved from http://www.icsu.org/publications/reports-and-reviews/icsu-foresight-analysis/download-report-1

Jarke, M. (1999). CREWS: Towards Systematic Usage of Scenarios, Use Cases and Scenes. In *Proceedings 4. Wirtschaftinformatik Tagung 1999* (Vol. 25, pp. 469–486). Springer.

Kaiser, S. O., Eickenbusch, H., Grimm, V., & Zweck, A. (2008). *The future of the car,* Zukünftige Technologien 75, VDI Technologiezentrum.

Kalmbach, R., Bernhart, W., Grosse Kleimann, P., & Hoffmann. M. (2011). *Automotive landscape 2025: Opportunities and challenges ahead,* Roland Berger Strategy Consultants.

Karaim, R. (2009). Future of globalization: Is the recession triggering deglobalization? *CQ Global Researcher*, *3*(9), 103–167.

Kessler, E. H., & Bierly, P. E. (2002). Is faster really better? *IEEE Transactions on Engineering Management*, *49*(1), 2–12.

Kessler, E. H., & Chakrabarti, A. K. (1996). Innovation Speed: A Conceptual Model of Context, Antecedents, and Outcomes. *The Academy of Management Review*, *21*(4), 1143–1191.

Khakee, A. (1991). Scenario construction for urban planning. *Omega*, *19*(5), 459–469.

Kilimann, S. (2011, October 31). Auto ohne Lenksäule. *Zeit Online*. Retrieved from http://www.zeit.de/auto/2011-10/autotechnik-elektronik-lenkung/seite-1

Kosow, H. & Gassner, R. (2008a). *Methods of future and scenario analysis: Overview, assessment, and selection criteria* (DIE Research Project "Development Policy: Questions for the Future"). Bonn.

Kosow, H., & Gassner, R. (2008b). *Methoden der Zukunfts- und Szenarioanalyse: Überblick, Bewertung und Auswahlkriterien*. Berlin: IZT.

Krys, C. (2011). *Trend Compendium 2030.*

Kvale, S. (2007). Doing interviews. *The SAGE Qualitative research kit*, London; SAGE.

Lee, H. (2003). The Effect of New Product Radicality and Scope on the Extent and Speed of Innovation Diffusion. *Journal of Management*, *29*(5), 753–768.

Lee, P.-C., Su, H.-N., & Wu, F.-S. (2010). Quantitative mapping of patented technology — The case of electrical conducting polymer nanocomposite. *Technological Forecasting and Social Change*, *77*(3), 466–478.

Lehman, M. M., & Belady, L. A. (1985). *Program evolution: Processes of software change*. London ;, Orlando: Academic Press.

Lerner, W. (2011). *The future of urban mobility: Towards networked, multimodal cities of 2050,* Arthur D. Little future lab.

Lewin, D., Adshead, S., Glennon, B., Williamson, B., Moore, T., Damodaran, L., & Hansell, P. (2010). *Assisted living technologies for older and disabled people in 2030,* Plum Consulting.

Lindgren, M., & Bandhold, H. (2003). *Scenario Planning: The Link between Future and Strategy*. New York: Palgrave Macmillan.

Martelli, A. (2001). Scenario building and scenario planning: state of the art and prospects of evolution. *Futures Research Quarterly*, 57–70.

Mason, D. H. (1994). Scenario-based planning: Decision model for the learning organization. *Strategy & Leadership*, *22*(2), 6–11.

Mayring, P. (2007). *Qualitative Inhaltsanalyse: Grundlagen und Techniken* (9th ed.). Weinheim [u.a.]: Beltz.

Meuser, M., & Nagel, U. (2002). Vom Nutzen der Expertise: ExpertInneninterviews in der Sozialberichterstattung. In A. Bogner, B. Littig, & W. Menz (Eds.), *Das Experteninterview. Theorie, Methode, Anwendung* (pp. 257–272). Opladen: Leske und Budrich.

Mićić, P. (2007). *Das ZukunftsRadar: Die wichtigsten Trends, Technologien und Themen für die Zukunft* (2nd ed.). *Gabal Management*. Offenbach: Gabal.

Mietzner, D., & Reger, G. (2005). Advantages and disadvantages of scenario approaches for strategic foresight. *International Journal of Technology Intelligence and Planning*, *1*(2), 220.

Mietzner, D., & Reger, G. (2009a). Practices of strategic foresight in biotech companies. *International Journal of Innovation Management*, *13*(02), 273.

Mietzner, D., & Reger, G. (2009b). *Strategische Vorausschau und Szenarioanalysen: Methodenevaluation und neue Ansätze* (1st ed.). Wiesbaden: Gabler.

Mihm, A. (2012, April 17). Der CO2-Ausstoß wird billig. *Frankfurter Allgemeine Zeitung*. Retrieved from http://www.faz.net/aktuell/wirtschaft/wirtschaftspolitik/klimaschutz-der-co2-ausstoss-wird-billig-11719914.html

Miller, C. C., & Cardinal, L. B. (1994). Strategic planning and firm performance: a synthesis of more than two decades of research. *Academy of Management Journal*, *37*(6), 1649–1665.

Mills, R. (2011). *Germany unplugged*. Retrieved from http://www.mining.com/2011/07/07/germany- unplugged/

Mintzberg, H. (1994). *The rise and fall of strategic planning: Reconceiving roles for planning, plans, planners*. New York, Toronto: Free Press; Maxwell Macmillan Canada.

Mißler-Behr, U. (1993). *Methoden der Szenarioanalyse*. Wiesbaden: Deutscher Universitäts Verlag.

Mudalige, U. P. (March 10), GM Global Technology Operations US 2010256852 A1. USA.

n.u. (2009). Turning their backs on the world. *The Economist*, pp. 34–36.

Nationale Plattform Elektromobilität. (2011). *Zweiter Bericht der Nationalen Plattform Elektromobilität*. Retrieved from http://www.siemens.de/elektromobilitaet/pdf/NPE-Zweiter-Bericht.pdf

Ou, X., Zhang, X., & Chang, S. (2010). Scenario analysis on alternative fuel/vehicle for China's future road transport: Life-cycle energy demand and GHG emissions. *Energy Policy*, *38*(8), 3943–3956.

Pannkoke & Seitz (2010). *Material Innovativ Material Innovativ - Faserverbundwerkstoffe und Hightech-Metalle für Automobil und Maschinenbau: Nachbericht*. Augsburg. Retrieved from http://bayern-innovativ.de/material2010/nachbericht

Patzelt, W. J. (2003). *Einführung in die Politikwissenschaft: Grundriß des Faches und studiumbegleitende Orientierung* (5th ed.). Passau: Wissenschaftsverlag Richard Rothe.

Pearson, I. (2010). Business 2020. In Ernst & Young (Ed.), *Business redefined. A look at the global trends that are changing the world of business* (pp. 2–30).

Peters, S. (2011). *Materialrevolution - Nachhaltige und multifunktionale Materialien für Design und Architektur*. Basel: Birkhäuser.

Phelps, R., Chan, C., & Kapsalis, S. (2001). Does scenario planning affect performance? Two exploratory studies. *Journal of Business Research*, *51*(3), 223–232.

Pile, J. (2003). *Interior Design* (3rd). New Jersey, USA: Pearson.

Potter, S., & Roy R. (2000). Using scenarios to identify innovation priorities in the UK railway industry. *International Journal of Innovation Management*, *4*(2), 229–252.

Powell, T. C. (1992). Strategic planning as competitive advantage. *Strategic Management Journal*, *13*(7), 551–558.

Random House Webster's college dictionary. (1999). New York: Random House.

Reibnitz, U. von. (1991). *Szenario-Technik: Instrumente für die unternehmerische und persönliche Erfolgsplanung*. Wiesbaden: Gabler.

Rhyne, L. C. (1986). The relationship of strategic planning to financial performance. Strategic Management Journal 7 (5), 423–436. *Strategic Management Journal*, *7*(5), 423–436.

Richter, B. (2010). *Das Konzept „Denken in Szenarien“ als Methode der sicherheitspolitischen Analyse* (Dissertation). Universität Wien, Wien.

Ringland, G. (1998). *Scenario Planning: Managing for the future* (1st ed.). Chichester: John Wiley & Sons.

Robertson, S. (2004). Scenarios in requirements discovery. In I. F. Alexander & N. Maiden (Eds.), *Scenarios, stories, use cases. Through the systems development life-cycle* (pp. 39–59). Chichester: Wiley.

Roche, C., Ducasse, P., & Liao, C. (2011). *Navigating in the new consumer realities,* Boston Consulting Group.

Rohrbeck, R., & Gemünden, H. G. (2011). Corporate foresight: Its three roles in enhancing the innovation capacity of a firm. *Technological Forecasting and Social Change*, *78*(2), 231–243.

Rolland, C., Ben Achour, C., Cauvet, C., Ralyté, J., Sutcliffe, A., Maiden, N. A., … (1998). A proposal for a scenario classification framework. *Requirements Engineering Journal*, *3*(1), 23–47.

Roussel, P. A., Saad, K. N., & Erickson, T. J. (1991). *Third generation R&D: Managing the link to corporate strategy*. Boston, MS: Harvard Business School Press.

Salancik, J. R., Wenger, W., & Helfer, E. (1971). The construction of Delphi event statements. *Technological Forecasting and Social Change*, *3*(5), 65–73.

Sarpong, D.; Maclean, M. (2011). Scenario thinking: a practice-based approach for the identification of opportunities for innovation. *Futures*, 43, 1154–1163.

SARTRE. (2012). *The SARTRE project*. Retrieved from http://www.sartre-project.eu/en/Sidor/default.aspx

Saunders, M., Lewis, P., & Thornhill, A. (2009). *Research methods for business students* (5th ed.). Harlow: Financial Times Prentice Hall.

Schlesinger, M., Lindenberger, D., Lutz, C., Hofer, P., Kemmler, A., Kirchner, A., & Strassburg, S. e. a. (2010). *Energieszenarien für ein Energiekonzept der Bundesregierung: Projekt Nr. 12/10 des Bundesministeriums für Wirtschaft und Technologie.*

Schwartz, P. (1996). *The art of the long view: Planning for the future in an uncertain world*. New York: Doubleday.

Shell Deutschland Oil GmbH. (2009). *Shell PKW Szenarien bis 2030: Fakten, Trends und Handlungsoptionen für nachhaltige Auto-Mobilität*. Retrieved from http://www-static.shell.com/static/deu/downloads/aboutshell/our_strategy/mobility_scenarios/shell_mobility_scenarios.pdf

Shell International. (2003). *Scenarios: An Explorer's Guide, Exploring The Future*. Retrieved from http://www-static.shell.com/static/public/downloads/brochures/corporate_pkg/scenarios/explorers_guide.pdf

Shenton, A. K. (2004). Strategies for ensuring trustworthiness in qualitative research projects. *Education for Information*, 22, 63–75.

Shoemaker, P. J. (1993). Multiple Scenario Development: Its Conceptual and Behavioral Foundation. *Strategic Management Journal*, *14*(3), 193–213.

Shoemaker, P. J. (1995). Scenario planning: a tool for strategic thinking. *Sloan Management Review*, *36*(2), 25–40.

Shoemaker, P. J. (2002). *Profiting from Uncertainty - Strategies for Succeeding No Matter What the Future Brings*. New York: The Free Press.

Shofield, J. W. (2002). Increasing the generalzability of qualitative research. In A. M. Huberman & M. B. Miles (Eds.), *The qualitative research companion* (pp. 201–232). Thousand Oaks: SAGE Publications.

Sikken, B. J., Davis, N., Hayashi, C., & Olkkonen, H. (2008). *Financing demographic shifts: The future of pensions and healthcare in a rapidly ageing world*, World Economic Forum, Geneva.

Simon, W. (2011). *GABALs großer Methodenkoffer*. Offenbach am Main: Gabal.

Simpson, D. G. (1992). Key lessons for adopting scenario planning in diversified companies. *Strategy & Leadership*, *20*(3), 10–48.

Sommerville, I., & Sawyer, P. (2006). *Requirements engineering: A good practice guide* (Reprinted). Chichester: Wiley.

Sood, A., & Tellis, G. S. (2005). Technological evolution and radical innovation. *Journal of Marketing*, *69*, 152–168.

Stake, R. E. (1994). Casestudies, in: *Handbook of qualitative research*, N. K. Denzin and Y. S. Lincoln. Thousand Oaks: Sage.

Strolz, R. (2007). *Die Szenario-Technik für organisatorische Entscheidungen* (1st ed.). s.l: GRIN Verlag. Retrieved from http://ebooks.ciando.com/book/index.cfm/bok_id/131735

Sutcliffe, A. (2003). Scenario-based requirements engineerung, mini-tutorial. In 11th IEEE International Conference on Requirements Engineering (Ed.), *Proceedings of the 11th International Conference on Requirements Engineering* (pp. 320–329).

Takigawa, T., Saijo, Y., Morimoto, K., Nakayama, K., Shibata, E., Tanaka, M. (2012). A longitudinal study of aldehydes and volatile organic compounds associated with subjective symptoms related to sick building syndrome in new dwellings in Japan. *Science of The Total Environment*, *417-418*, 61–67.

Taub, A. I. (2006). Automotive Materials: Technology Trends and Challenges in the 21st Century. *MRS Bulletin*, *31*(04), 336–343.

Turton, H. (2006). Sustainable global automobile transport in the 21st century: An integrated scenario analysis. *Technological Forecasting and Social Change*, *73*(6), 607–629.

U.S. Energy Information Administration. (2011). *Annual Energy Outlook 2011 with projection to 2035*. Retrieved from http://205.254.135.7/forecasts/aeo/pdf/0383(2011).pdf

UNdata. (2010). *World population prospects: The 2010 revision*. Retrieved from http://data.un.org/Data.aspx?q=median+age&d=PopDiv&f=variableID%3a41

United Nations, Population Division Department of Economic and Social Affairs (2010). *Population Projections,* UN Publication ST/ESA/SER.A/179, New York.

van der Heijden, K. (1998). *Scenarios: The art of strategic conversation* ([Reprinted]). Chichester [etc.]: J. Wiley.

van der Heijden, K. (2002). *Sixth sense: Accelerating organizational learning with scenarios*. Chichester: Wiley.

van der Heijden, K. (2009). *Scenarios: The art of strategic conversation* (2nd ed.). Chichester: Wiley.

van Notten, P. W. F. (2005). *Writing on the wall: Scenario development in times of discontinuity*. Boca Rotan, FL: Dissertation.com.

van Notten, P. W. F., Rotmans, J., van Asselt. M., & Rothman, D. S. (2003). An updated scenario typology. *Futures*, *35*(5), 423–443.

Varum, C. A., & Melo, C. (2010). Directions in scenario planning literature – A review of the past decades. *Futures*, *42*(4), 355–369.

von der Gracht, H. A., & Darkow, I.-L. (2010). Scenarios for the logistics services industry: A Delphi-based analysis for 2025. *International Journal of Production Economics*, *127*(1), 46–59.

von der Gracht, H. A., & Stillings, C. (2012). An innovation-focused scenario process — A case from the materials producing industry. *Technological Forecasting & Social Change*, article in press.

von der Gracht, H. A., Vennemann, C. R., & Darkow, I.-L. (2010). Corporate foresight and innovation management: A portfolio-approach in evaluating organizational development. *Futures*, *42*(4), 380–393.

van der Wiel, J. W. (2012). *Future of automotive design and materials: Trends and development in design and materials.*

Wack, P. (1985). Scenarios: Shooting the rapids. *Harvard Business Review*, *85*(6), 139–150.

Weiss, T. (2011). *Unser Auto von morgen: Studie zu den Wünschen der Deutschen an das Auto von morgen,* AutoScout24.

Wicke, L., Schellnhuber, H. J., & Klingenfeld, D. (2010). *Die 2°max-Klimastrategie: Ein Memorandum*. *Studien zur internationalen Umweltpolitik: Vol. 13*. Münster: LIT.

Wiehler, G. (2004). *Mobility, security and web services: Technologies and service-oriented architectures for a new era of IT solutions*. Weinheim, Great Britain: Publicis Corporate Publishing. Retrieved from http://site.ebrary.com/lib/alltitles/docDetail.action?docID=10308263

Wilkinson, L. (1995). How to Build Scenarios: Planning for "long fuse, big bang" problems in an era of uncertainty. *Wired "Scenarios: The Future of the Future" Special Edition*, *Special Edition*, 1–4.

Wilson, R. M., & Gilligan, C. *Strategic marketing management: planning, implementation & control* (3rd ed.). Oxford: Elsevier Butterworth-Heinemann.

Winterhoff, M., Kahner, C., Ulrich, C., Sayler, P., & Wenzel, E. (2009). *Future of mobility 2020: The Automotive Industry in Upheaval?,* Arthur D. Little future lab.

Wright, D., Gutwirth, S., Friedewald, M., Vildjiounaite, E., & Punie, Y. (Eds.). (2010). *The international library of ethics, law and technology: Vol. 1*. *Safeguards in a world of ambient intelligence* (1st ed.). Dordrecht: Springer.

Wright, G., & Cairns, G. (2011). *Scenario Thinking: Practical Approaches to the Future*. London: Palgrave Macmillan.

Wulf, T., Brands, C., & Meißner, P. (2011). *A scenario-based approach to strategic planning: Tool Description - Impact/Uncertainty Grid* (Working Paper No. 5). Leipzig. Retrieved from http://www.scenariomanagement.de/fileadmin/user_upload/Tool_Description_Impact_Uncertainty_Grid_FINAL.pdf

Wulf, T., Meißner, P., & Stubner, S. (2010). *A Scenario-based Approach to Strategic Planning – Integrating Planning and Process Perspective of Strategy* (Working Paper). Leipzig. Retrieved from http://www.hhl.de/fileadmin/texte/publikationen/arbeitspapiere/hhlap0098.pdf

z_punkt. (2012). *Megatrends update*, z_punkt, Köln.

Zegras, C., Sussman, J., & Conklin, C. (2004). Scenario Planning for Strategic Regional Transportation Planning. *Journal of Urban Planning and Development*, *130*(1).