Schaffer René Uwe, BSc

Strategic Analysis of Tool Steel Potential in Emerging Automotive Markets

Master Thesis

Production Science and Management

Graz University of Technology
Faculty of Mechanical Engineering and Economic Sciences

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Univ.-Prof. Dipl.-Ing. Dr. techn. Christian Ramsauer

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Abstract

The purpose of the thesis is to forecast the tool steel potential for manufacturing of structural car body parts in emerging automotive markets, strictly speaking for China and India with Europe as a benchmark. The investigation starts with analysing the market development in the different regions, the legal restrictions in terms of emissions, the development in the powertrain sector and the car body structure. The growth in Asia is one of the main drivers in automotive industry today. Stricter CO2 emission regulations force car manufacturers to develop more efficient vehicles and make use of lightweight design. All these factors influence the material selection for the car body structure and further the manufacturing process. The final focus is put on press hardening of structural parts as it turned out that this technology will see an increased use within the next years. This results in a forecast which shows that there is an increasing demand for press hardening tool steel due to the fact that the automotive industry is demanding more and more structural press hardened parts for the car body.

Kurzfassung

Diese Arbeit untersucht die Entwicklung der potentiellen Nachfrage nach Werkzeugstahl zur Herstellung von Strukturbauteilen in aufstrebenden Märkten der Automobilindustrie, speziell für Indian und China wobei Europa als Vergleichsmarkt diente. Zuerst wurde die Entwicklung der Märkte in den 3 Regionen untersucht, darauffolgend die gesetzlichen Bestimmungen hinsichtlich CO2 Emissionen, die Entwicklungen im Bereich des Antriebsstranges und abschließend die Materialien die in der Karosseriestruktur zur Anwendung kommen. Der asiatische Markt wächst stetig und ist daher von großer Bedeutung für die Automobilindustrie. Strengere gesetzliche Bestimmungen hinsichtlich der CO2 Emission zwingen die Autohersteller effizientere und leichtere Fahrzeuge zu bauen. All diese Faktoren beeinflussen die Materialauswahl für die Karosseriestruktur was sich direkt auf deren Herstellungsprozess auswirkt. Der Fokus wurde schlussendlich auf das Presshärten von Strukturbauteilen gerichtet da die Untersuchungen ergeben haben, dass diese Technologie in Zukunft vermehrt Anwendung im Bereich der Karosseriestruktur finden wird. Das Ergebnis der Berechnung ist dass sich aufgrund des steigenden Bedarfs an pressgehärteten Bauteilen für die Karosseriestruktur auch die Nachfrage nach Werkzeugstahl hierfür erhöhen wird.

Contents

1 Introduction

The idea to this master´s thesis arose during an internship at Uddeholms AB concerning the future developments in emerging automotive markets. It turned out that this topic is very extensive and complex and requires further investigation. This was the starting signal for the thesis.

1.1 Uddeholms AB

Uddeholms AB is a leading supplier of tooling materials. They offer a wide range of tooling and component-materials in a wide variety of dimensions and executions, standard grades as well as customized. The product portfolio ranges from tool steel for hot-work, cold-work and plastics applications to steel for components in the racing industry, manufacturing industry, recycling industry, and many more up to a product segment called granshots. Granshot is a prealloyed and granular meltstock suitable for foundries. Sweden is the base for all Uddeholm production, research and development. The head office is in Hagfors, province Värmland and right next door to the production facility. Today Uddeholm has 3000 employees all over the world whereof 900 are in the steel mill in Hagfors. In Asia Pacific and India, Uddeholm is represented by ASSAB (Associated Swedish Steel Aktiebolag).[1]

The company was founded in 1668 and named Uddeholm, one of Värmland´s largest farms at the time. It was privately held until 1870 when it was re-formed as a public share company called Uddeholms AB. The 19th century was a time of modernisation for the company and the blast furnace pipe at the new ironworks in Hagfors was filled for the first time in 1878. After the end of 2nd world war 1945, ASSAB was formed from the four cooperating Swedish steel producers Uddeholm, Fagersta Bruks AB, Hellefors Jernverks AB and Sandvikens Jernverks AB with the aim of jointly exploiting the opportunities to develop business in Asia east of Burma, Africa and in Latin America. In 1976 Uddeholm bought the others out and ASSAB thus became a wholly-owned subsidiary of Uddeholm. In 1990 trustor opens talks with Austrian company voestalpine Stahl AG about a merger between Uddeholm and their subsidiary Böhler and in 1991 the companies joint and formed the Böhler-Uddeholm

[1] Uddeholms AB, www.uddeholm.com/About_us, accessed 23th March 2013

AG. In 2007 the Austrian steel group voestalpine AG took over the whole of Böhler-Uddeholm AG which later forms the fifth division, special steel, of voestalpine AG.[2]

1.2 Definition of Tasks and Goals

The economic development in the last years showed a huge growth in the Asian countries, especially in India and China. Due to this fact more and more people are able to afford a car which leads to a big growth potential for the automotive market. Uddeholms AB will benefit from this growth and the thesis should provide proper information to assess which possibilities are in this market for Uddeholms tooling applications. The established European market should serve as an object of comparison to evaluate the results in the emerging markets. Several indicators influence the market development and have to be assessed during the thesis to deliver a stable foundation for decision making. The main goal of the thesis is to predict the future tool steel potential in these markets.

1.3 Procedure

To reach the desired outcome the first step is to conduct a detailed literature research for creating the theoretical basis for the practical part. The theory explains how to gather the required and proper information, which tools are helpful and will lead to success. The technical part requires knowledge of how the parts are manufactured in the car industry, especially which manufacturing methods and processes are used.

The practical part is a stepwise approach to collect the necessary indicators. The first step is to investigate the development of the automotive market in Europe, India and China and which materials are used for the car body in the different countries. The used materials influence the manufacturing methods for the car parts and further this affects the tool steel selection. Together with the die life and future production trends it should be possible to predict the future tool steel potential in the mentioned areas. Figure 1-1 illustrates the practical procedure.

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[2] Uddeholms AB, www.uddeholm.com/timeline, accessed 23th March 2013

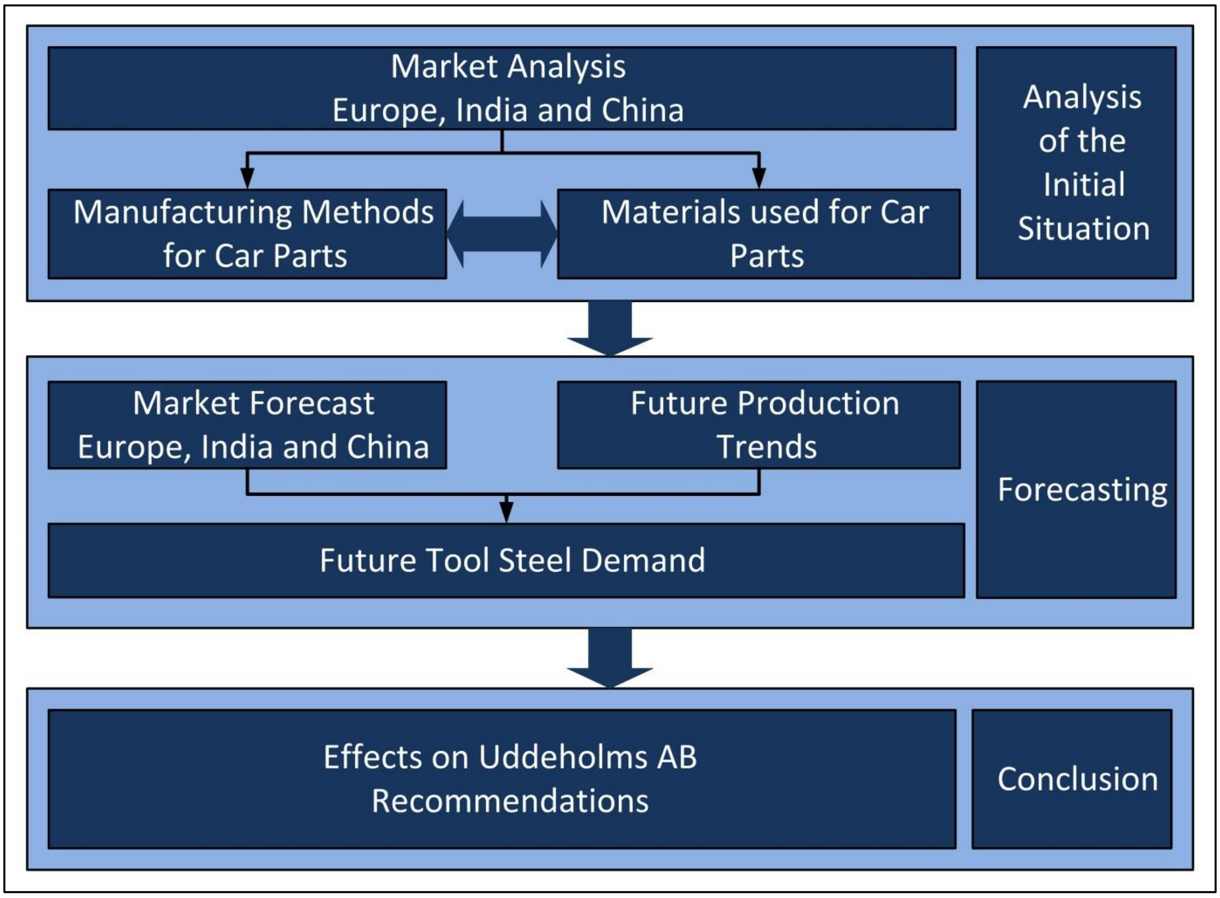

Figure 1-1: Practical Procedure

2 Basics of Market Analysis

Market analysis is a process which should figure out strategic and operational marketing problems. The market opportunities have to be assessed as well as the advantages and disadvantages of the firm in terms of competition. The question is: Where is the firm in competition? The forecasting is about the development of the market to assess and expose future market chances. This leads to the second question: Which relevant developments influence the market?[3]

2.1 Basic Market Characteristics

Marketing is a process in the economic and social structure through which persons and groups satisfy their needs and desires by creating, offering and exchanging products and other things of value. This approach of marketing is built on the following basic factors shown in Figure 2-1.[4]

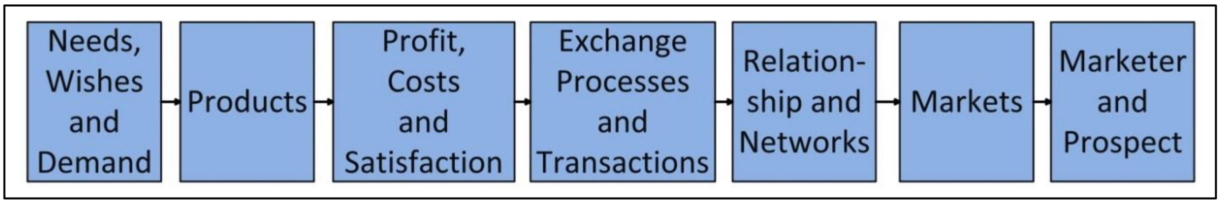

Figure 2-1: Basic Process of Marketing[5]

The initial points for marketing are the human needs and wishes. People need air, water, food, clothes and safety to survive. There is a difference between, needs, wishes and demand. Needs are a motivating force that compels action for its satisfaction. They are not created by the marketer but part of the human nature. Wishes express a craving after concrete satisfaction. For example: a guy needs food and desires a burger; he needs clothes and wants a suit from Hugo Boss. These wishes underlie constant changes which are driven by the society and institutions (companies, churches, family etc.). Demand describes the consumer´s desire after specific products in combination with the willingness to purchase this product or service. Wishes become demand if there is a corresponding purchasing power available. Many people want to drive a Porsche but just a few percent of the society

[3] Cf. Meffert (1992), pp. 5-6
[4] Cf. Kotler/Bliemel (1999), p. 8
[5] Cf. Kotler/Bliemel (1999), p. 8, own illustration

are able to buy one. So it is of outmost importance for companies to figure out how many people are able to buy their products.[6]

The definition of a product is broader. A product is everything which could be offered to a person to satisfy a need or desire. Product is in this connection an umbrella term for goods, services and immaterial objects. Physical products are in most cases not bought because the purchaser wants to possess these but for the benefits he can gain from it. For example people don't buy a microwave oven because it looks so well, they buy it heating up their food. That means that physical goods are just a way to become the desired service. A product can also consist of a combination of the components. For example a birthday dinner consist of physical goods (food and beverages), service (waiter/waitress etc.) and immaterial values (ambience of the restaurant).[7]

To describe the terms benefit, costs and satisfaction a short example should help. Someone has to cover 5 kilometres a day on the way to work. Now he/she can choose out of several products to satisfy this need: the person can walk, use a bicycle, go by car or bus and lots more. These possibilities result in a quantity of selections. On the way to work other needs like safety, economic efficiency, speed and others can be important. This leads to a quantity of needs. The next step would be to take a decision which possibility satisfies these needs the most. The criterion of decision which is now used is the benefit. Benefit is the assessment of the user, concerning the specifications of the product, in which extent it satisfies his needs. In this example the car would be the most comfortable, fastest and safest choice. Further the costs have to be considered. The car is the most expensive solution which is a great disadvantage. This leads to a comparison of benefits and costs. The consumer would decide for that product, which delivers the best combination of benefits and costs.[8]

Exchange is a process through which someone gets a specific product by offering something in return. The exchange process is a basis for marketing.[9]

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[6] Cf. Kotler/Bliemel (1999), pp. 8-9
[7] Cf. Lane Keller/Bliemel/Kotler (2007), pp. 12-13
[8] Cf. Lane Keller/Bliemel/Kotler (2007), pp. 13-14
[9] Cf. Runia et al. (2011), p. 3

Five conditions have to be fulfilled to accomplish an exchange:[10]

- There have to be two partners
- Every partner must have something which is of value for the other
- Every partner has to be able to communicate with the other one and deliver the product
- Every partner is allowed do accept or decline the offer
- Every partner may not decline the contact and decline with the other

Whether an exchange takes place or not depends on the partners. The question is if they reach an agreement or not. All participants want to create additional value for themselves. A transaction is, when they finally reach an agreement. Practically spoken this is done by a purchase contract which contains the agreed conditions. In best case the seller and the buyer create a long term relationship.[11]

Figure 2-2 illustrates the linkage between two partners.

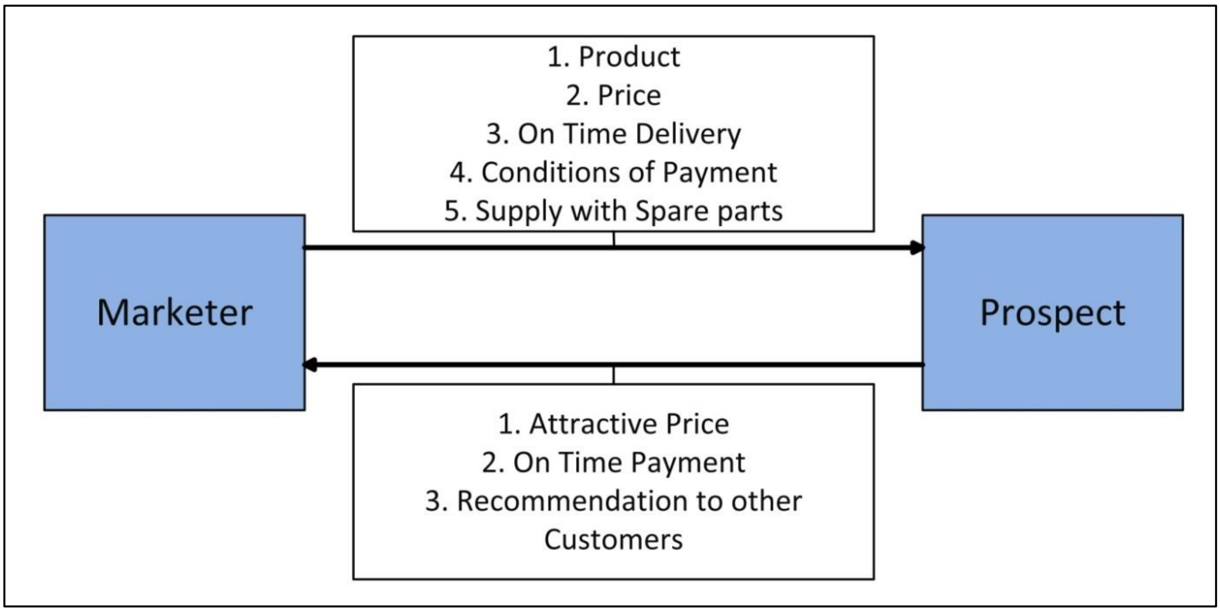

Figure 2-2: Exchange between two Partners[12]

Customer relationship marketing is about the creation and consolidation of long-term customer relationships through specialised and individual marketing-, sales- and service-concepts. [13]

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[10] Cf. Runia et al. (2011), p. 3
[11] ibidem
[12] Cf. Kotler/Bliemel (1999), p. 13, own illustration
[13] Cf. Hippner/Hubrich (2011), p. 18

The market itself is the whole economic relationship between supply and demand of a product within a designated place and time.[14]

Resources are limited for every enterprise. Therefore it is only possible to be active on a part of the whole market. There has to be a decision which is the relevant market. The clash of supply and demand on the market is influenced by the supply- and demand-function. First the supply-function shows the connection of the offered quantity by the manufacturer of a product on the market and the price. The offered quantity x_A will increase in the same ratio as the price p to which the product can be sold. That means the higher the possible price is for which a product can be sold the higher is the quantity of this product on the market. Second the demand-function shows the connection between the demanded quantity and the price. In other words, the lower the price p for a product the higher is the demand x_N for the product.[15]

Figure 2-3 and Figure 2-4 illustrate the supply- and demand-function.

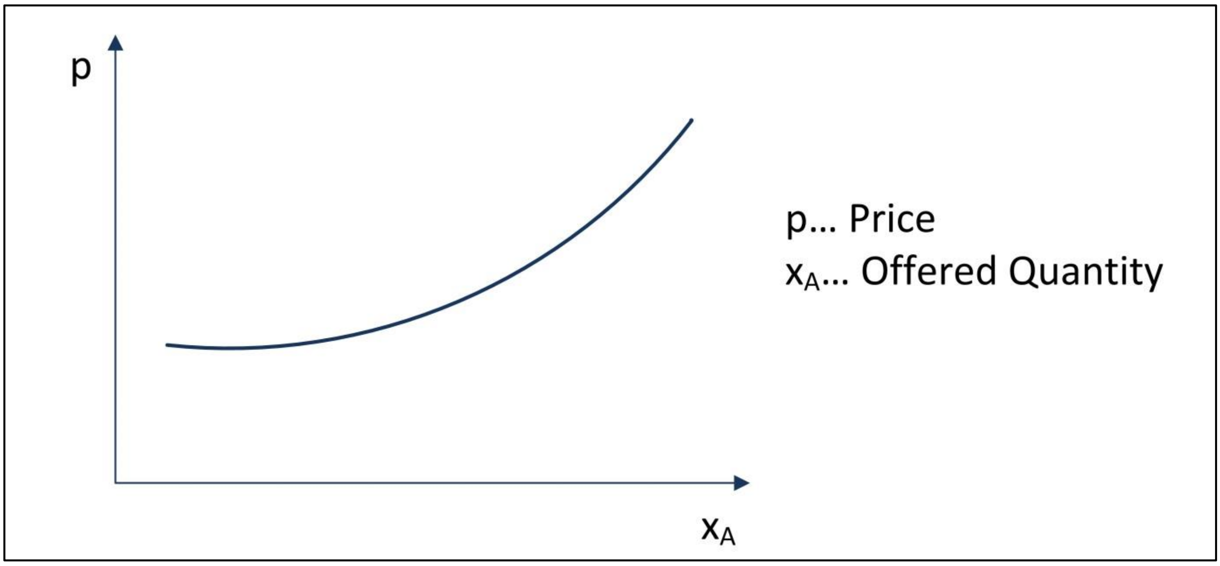

Figure 2-3: Supply-Function[16]

[14] Cf. Pepels (1995), p. 3
[15] Cf. Schwinn (1993), pp. 397-398
[16] Schwinn (1993), p. 397

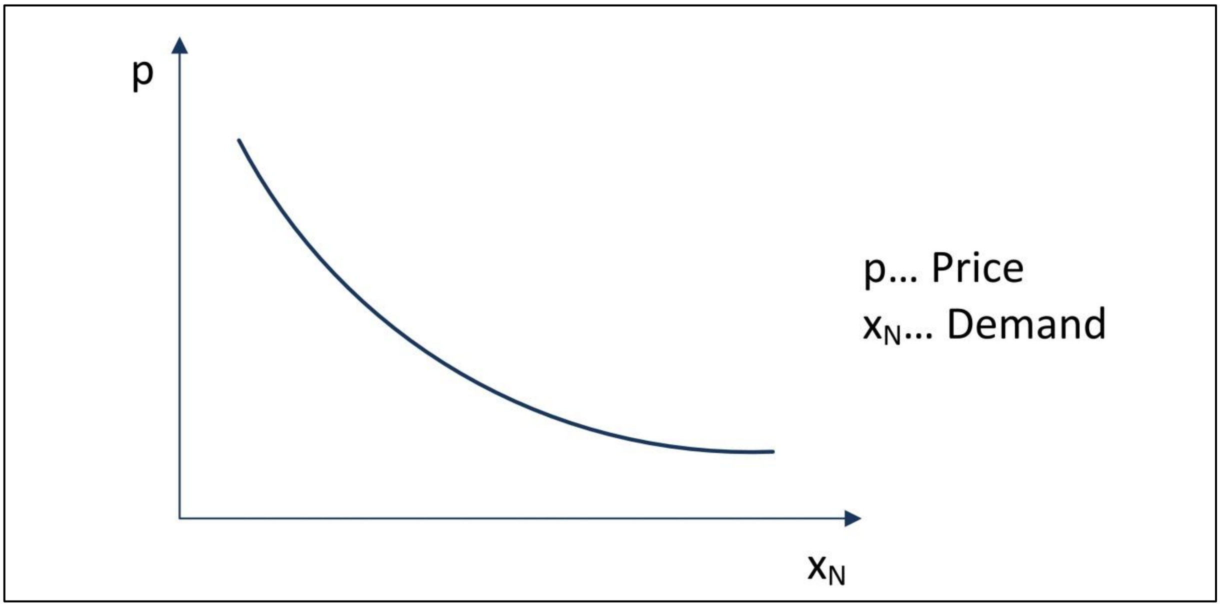

Figure 2-4: Demand-Function[17]

Marketing contents all activities of people in the markets. Marketing means to be active in these markets, to perform potential exchange processes to satisfy the needs and wishes of the people. Is one of the participants more active to carry out an exchange than the other one, we call him the marketer, the second one is called prospect. Marketers are searching for one or more prospects to exchange something of value. A prospect is somebody who is identified by the marketer as someone who is able and willing for an exchange. Summarized, marketing is a process in the economic and social structure through which individuals and groups satisfy their needs and desires by creating, offering and exchanging products and other things of value.[18]

2.2 **Concept of Marketing**

The basic idea of marketing is the consequent orientation of accompany towards the requirements of the market. The timely identification of market changes is one of the main tasks. Marketing is an entrepreneurial way of thinking which combines the analysis, planning, implementation and monitoring of all activities set within and outside the company.[19]

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[17] Schwinn (1993), p. 397
[18] Cf. Kotler/Bliemel (1999), p. 16
[19] Cf. Bruhn (2012), pp. 13-14

The understanding of marketing changed with time and led to the definition of the American Marketing Association: “Marketing is the activity, set of institutions, and processes for creating, communicating, delivering, and exchanging offerings that have value for customers, clients, partners, and society at large.”[20]

The tasks of modern marketing are planned, controlled and implemented in a systematic and structured process. This process is called marketing management. Generally there are two aspects; the customer side and the performance side as shown in Figure 2-5.[21]

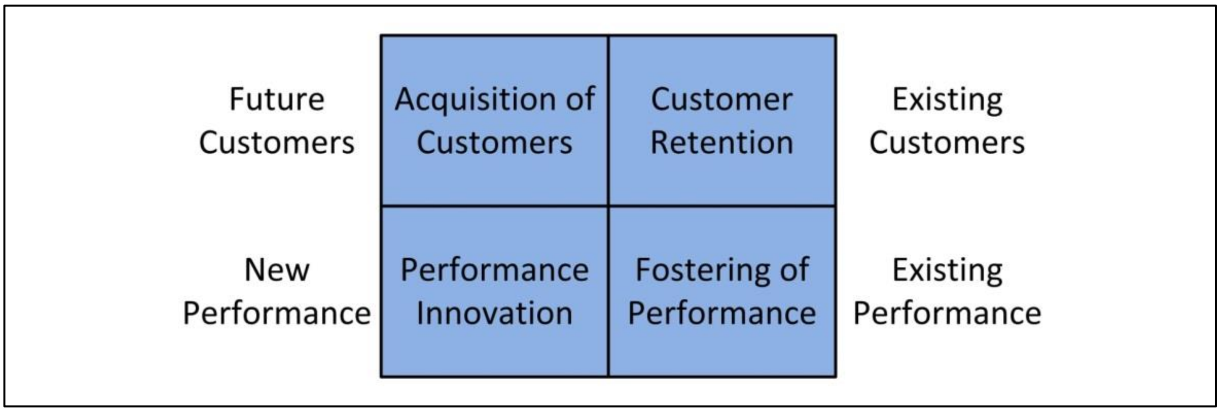

Figure 2-5: Four Basic Tasks of Marketing[22]

All tasks and activities of marketing can be concluded as one clearly identified process of decision making and implementation of decisions, called marketing management.[23]

Marketing management includes the following feedback tasks as shown in Figure 2-6.

[20] American Marketing Association, www.marketingpower.com/AboutAMA/Pages/DefinitionofMarketing.aspx, accessed March 4th 2013
[21] Cf. Meffert/Burmann/Kirchgeorg (2012), p. 18
[22] ibidem, own illustration
[23] Cf. Meffert/Burmann/Kirchgeorg (2012), p. 20

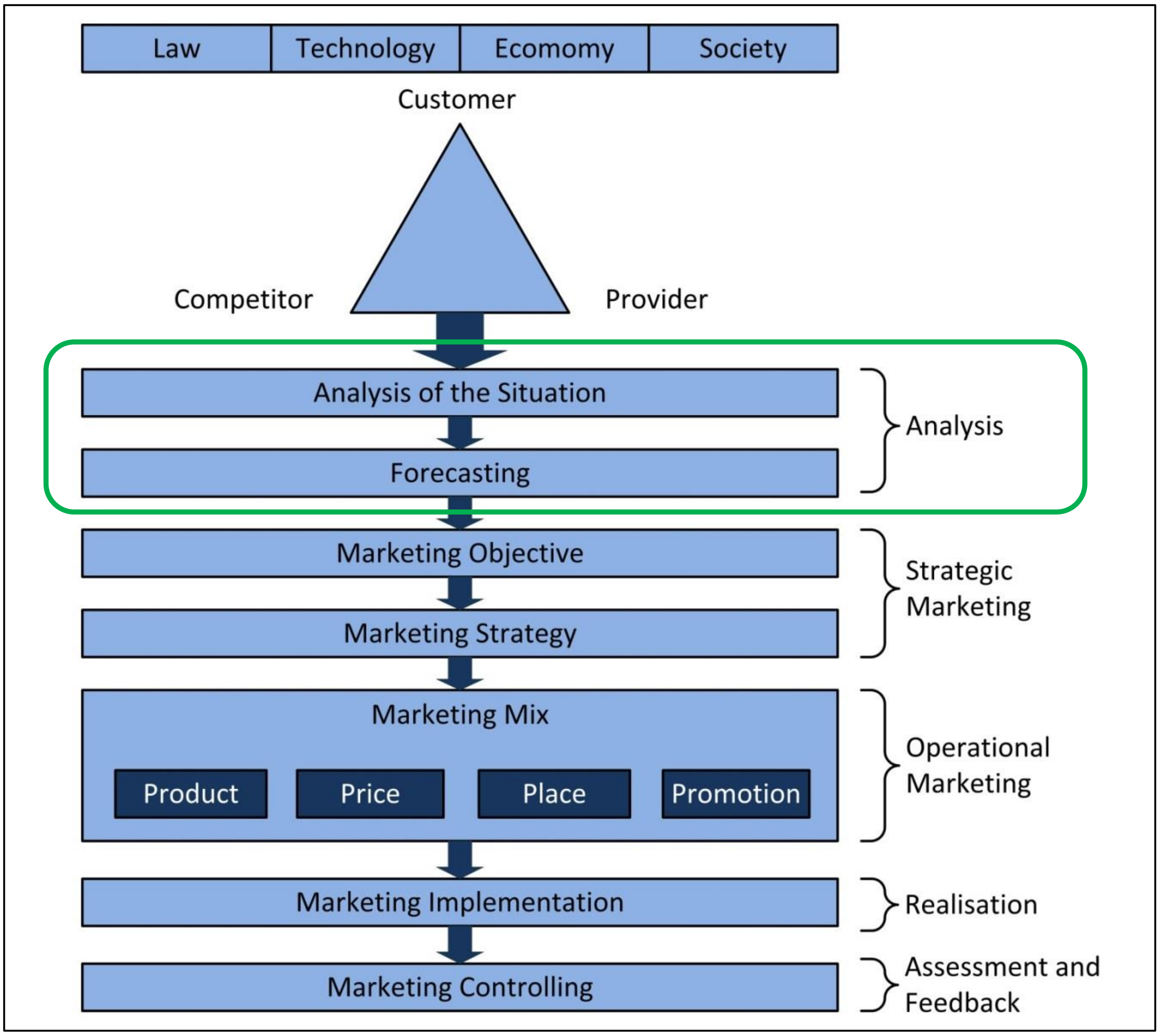

Figure 2-6: Tasks of Marketing as Management Process[24]

The focus of the thesis is on the overall analysis phase (green rectangle in Figure 2-6) with the analysis of the situation and the forecasting to deliver a basis for formulating the marketing objective.

2.3 Analysis of the Initial Situation

The analysis of the situation is the starting point of marketing management. The major task is to acquire company internally and externally information in terms of the initial situation to create a basis for strategic and operational marketing decisions. The major environmental- and market-conditions as well as the behaviour of market

[24] Cf. Meffert (2000), p. 14, own illustration

participants and relevant stakeholders have to be assessed. Out of this evaluation the threats and opportunities have to be compared with the strengths and weaknesses of the company in a systematic way.[25]

2.3.1 Market Research

Market research is inseparably connected with marketing because the orientation of offers and products to customers as well as the influencing of customers requirements depends on appropriate information about the market and customer.[26]

2.3.1.1 Tasks of Market Research

To satisfy the different needs of customers it is necessary to know the behaviour of the market where the company is active. Acquisition of proper information is the main task of market research. The development of new products can bear risks and chances for the company. The main risk is a failed market launch. Chances can be created if the firm is able to identify latent and manifest needs of the potential customer and to satisfy them by appropriate products and services. The risk of launching a new product can be lowered by product tests. Potential consumers are confronted with a prototype of the product or service to evaluate their willingness to buy. With the gathered knowledge it is possible to decide if the product is ready for the market or still some modifications have to be done. Another task is to monitor the used marketing instruments (like advertising control), development of new marketing instruments and the evaluation of potential needs of future customers. In this case the sales market is not seen as a whole but it is divided in several customer groups. The groups are built in a way that the needs within the group are preferably homogenous and between the groups as heterogeneous as possible. Instead of the needs customers have concerning a product or service, for example the art and manner how the customer groups are reached by different communication channels can be investigated. The result of such market segmentations can be two groups with the same product for testing but they are confronted with different communication strategies. Communication strategies are for example different packaging or product designs. The aim of market segmentation is to satisfy the heterogeneous needs of the customers to gain acceptance on the market. The idea behind this method is the hope that customers are buying more products for a higher price. The market

[25] Cf. Meffert/Burmann/Kirchgeorg (2012), p. 21
[26] Cf. Kuß (2012), p. 1

research has summarized the tasks to provide proper criterions to make a segmentation of the market, to figure out the needs and wishes of the defined market segments and to create strategies to reach the consumer within the specific segment.[27]

2.3.1.2 Process of Market Research

Systematic market research is marked by scientific research methods and a structured process of investigation.[28] Figure 2-7 illustrates the process.

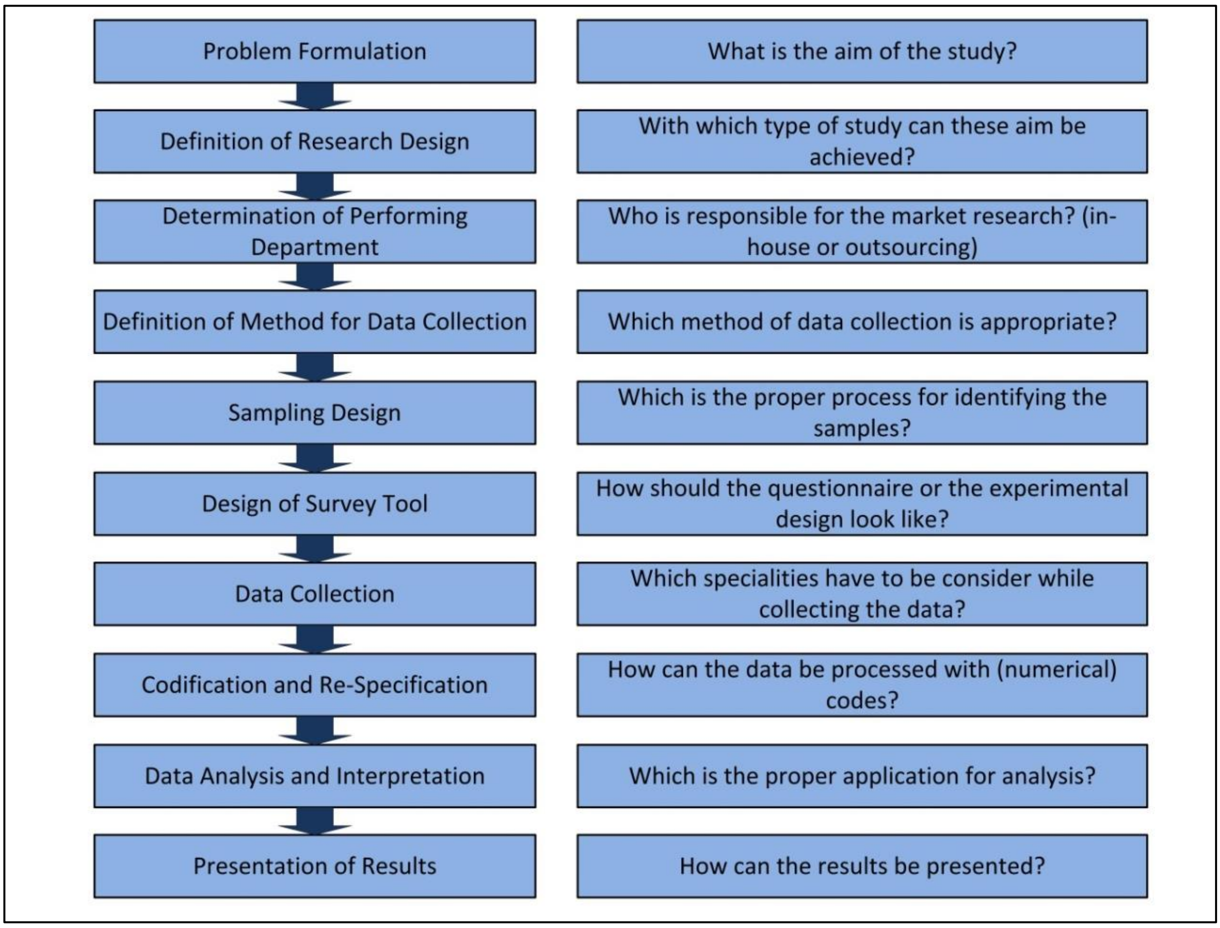

Figure 2-7: Process of Market Research[29]

[27] Cf. Olbrich/Battenfeld/Buhr (2012), pp. 9-10
[28] Cf. Herrmann, A et al. (2008) quoted from Homburg/Krohmer (2009), p. 242
[29] Cf. Homburg/Krohmer (2009), p. 243, own illustration

The steps are defined as follows:[30]

- The phase of problem formulation tries to translate the question of the managers into a research problem and defines the aims of the market research study. In this early phase it is of outmost importance that the market researchers understand the requests of the decision makers and the firm. Therefore a tight cooperation between market researchers and managers is necessary.
- The definition of research design is responsible for the choice of study type (descriptive, explorative and explicative). Depending on the aim of the study a different type can be the proper one. Further it is possible to create hypothesis on connections between the investigated variables.
- The determination of the performing department can distinguish between the firm (or parts of it) itself or outsourcing to a market research institute.
- To define the method for data collection is the next step. Several methods are available which, depending on the aim of the study, are more or less suitable. It is also possible to combine a few methods. Often a qualitative pre-research is followed by a quantitative main-research.
- Sampling design decides if it is necessary to investigate all relevant objects or just a few of them. In the case that only a few relevant objects are considered it has to be declared how these objects are chosen, random or conscious.
- Survey tool design defines in which way the data are set in context with the data collection method.
- Data collection builds the basis of market research. Within a market research new primary data can be collected by a market study or existing data (secondary data) can be used.
- Within the scope of re-specification is ensured that the required data is available, faultless and readable. It has to be decided what to do with data which are unclear or unreadable. These data can be used partly or removed completely. Codification is the process of categorization of raw data. Raw data is separated in response categories and translated into numbers if necessary.
- Data analysis and interpretation uses statistical methods to handle the often vast amount of data and generate meaningful information out of it.

[30] Cf. Homburg/Krohmer (2009), pp. 242-307

- The last step presents the results to the involved departments of the company. It is important to prepare the presentation in a way that it is possible to understand the results even without detailed knowledge of the study.

2.3.1.3 Criterions of Market Research

The goal of the measuring is the acquisition of faultless and exact data. This aim is reached very seldom because of the fact that measured values always contain measurement errors.[31]

This led to the three main criterions:[32]

- Validity
- Reliability
- Objectivity

Validity means that an investigation method is true when it measures the feature which it should measure. The used test items should represent the target feature as good as possible. Validity can be influenced by a variety of factors. Tiredness or misunderstanding can have a negative effect on the test behaviour of the test person as well as formal reaction tendencies like the tendency to say yes (acquiescence) and the tendency to the middle. A further known point is that test persons change their behaviour when they are monitored. Another effect is the Rosenthal-effect which describes the influence on the test person because of the expectations of the examiner. All these factors lower the validity of the study and have to be avoided as good as possible.[33]

Reliability defines the formal accuracy of the feature selection. Reliability is a necessary but not sufficient requirement for validity. A measurement device is under constant measurement conditions reliable, when the measured values are precise and stable. That means that they are reproducible by repeated measuring of the same specifications at the same features.[34]

[31] Cf. Opresnik/Rennhak (2012), p. 137
[32] ibidem
[33] Cf. Theobald/Dreyer/Starsetzki (2003), pp. 144-145
[34] Cf. Theobald/Dreyer/Starsetzki (2003), p. 139

Objectivity means that results by the measuring are independent from the examiner. A measuring is objective when examiners who are independent from each other get the same results.[35]

2.3.1.4 Methods of Information Acquisition

Marketing relevant information can be gathered by primary- and secondary- market research.[36] Figure 2-8 gives an overview.

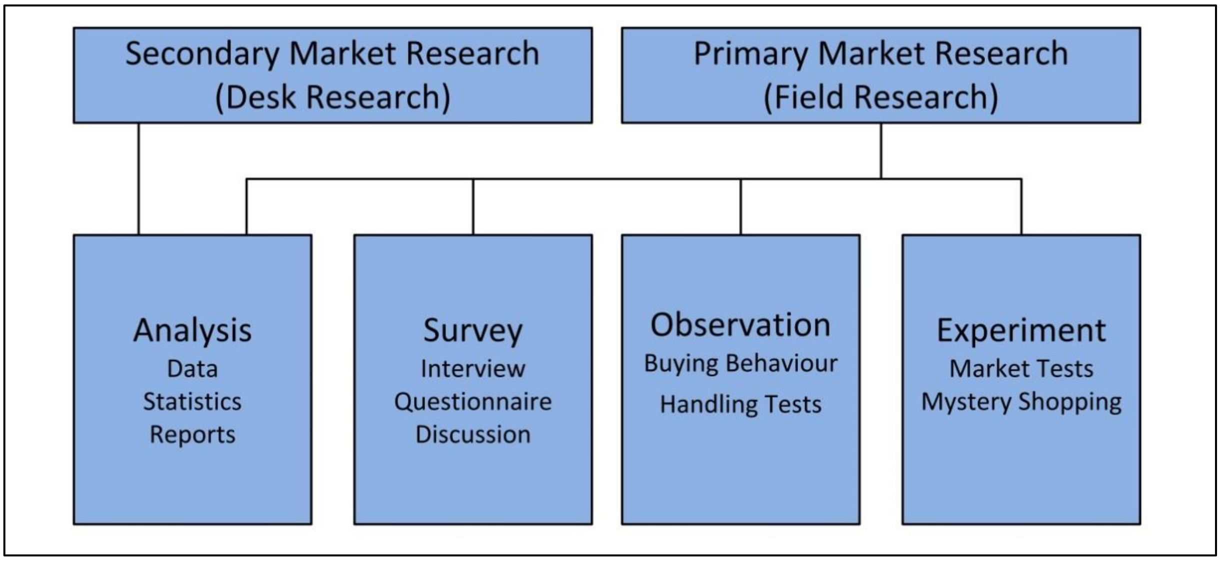

Figure 2-8: Primary- and Secondary-Market Research[37]

Secondary market research includes the procurement, composition and evaluation of existing data and information. This type of research has enormous data from internal and external sources. The importance of internal and external sources cannot be determined in general. Secondary data are initial data which should help to get familiar with the problem. In contrast to primary data, secondary data is faster and cheaper to gather. The tool for acquiring secondary data is the empirical content analysis. This analysis defines the categories of relevant features in advance which are identified statistics, reports and existing data.[38]

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[35] Cf. Homburg/Krohmer (2009), p. 246
[36] Cf. Broda (2002), p. 57
[37] Cf. Broda (2002), p. 57, own illustration
[38] Cf. Meffert/Burmann/Kirchgeorg (2012), p. 156

There are three different types of content analysis: [39]

- Frequency analysis: The easiest approach to work in a content-analytic way is to count determined elements of the available material and to compare their frequency with other elements. One example is to count origin of the main characters in American comics and compare it with the real distribution in the American society.
- Valence- and intensity-analysis: In this type of content analysis determined text-elements are scaled in a single- or multi- stage assessment scale. An easy example is to compare the main political articles of the daily newspapers if they are more on the side of the governing party or the opposition.
- Contingency analysis: The aim of this method is to figure out if determined text-elements (like main-terms) appear in the same context, that they are contingent. The aim is to filter out a structure of associated text-elements.

Some typical applications for secondary market research are:[40]

- Sales and market share analysis: The goal is to estimate market shares of competitors, broken down by application, product, region and so on. Sales trends, growth rates and other characteristics are used for this analysis.
- Trend analysis: The aim of a report can be to go beyond collecting and reporting specific numbers to encompass interpretation and analysis of underlying dynamics, success factors and the like.
- Customer segmentation: The approach is to group the customers and figure out their particular needs and requirements of each segment.
- Competitor analysis: Analysing and investigation of business and marketing strategies of key competitors can show their particular strengths and weaknesses of products and describes markets in which each competitor enjoys advantage or suffer disadvantages.

In spite of the varied availability of secondary information and their fields of application, the use of secondary research is limited. Especially in terms of comparability of information from different sources, the accuracy of the information, the degree of detail and the extent of the useable information.[41]

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[39] Cf. Mayring (2010), pp. 13-16
[40] Cf. McQuarrie (1996), pp. 46-47
[41] Cf. Pepels (1995), p. 176

Primary market research is used when the secondary data is not sufficient enough. This type of market research is generally more expensive and deals with so far not collected data.[42] Primary research uses normally three ways of information acquisition:[43]

- Survey
- Observation
- Experiment

The survey is the most important data collection method. Oral or written questions and other stimuli like pictures are used to get appropriate information from the target group.[44]

Basically the type of survey can be distinguished between the following characteristics:[45]

- Target- person/group
    - Individual person
    - Groups
    - Experts
    - Households
    - Companies (industry/service)
- Type of communication
    - Face-to-face
    - Orally via phone
    - Written
    - Computer aided
    - Online via internet
- Type of survey
    - Direct
    - Indirect
- Degree of standardization
    - Open discussion/free interview
    - Structured interview
    - Standardised interview
- Frequency of survey

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[42] Cf. Koch (2010), p. 47
[43] ibidem
[44] Cf. Pepels (1995), p. 181
[45] Cf. Koch (2010), pp. 47-48

  - One time or ad-hoc survey
  - Repeated survey
  - Panel survey
- Extent of the topic
  - One topic survey
  - Several topics / Omnibus survey

The popular tools are individual interviews, focus groups, standardised oral or written surveys.[46]

The individual interview, also free or qualitative interview, is a personal oral questioning. The questions and procedures are not pre-formulated but the interviewer tries to guide the test person to the specific topic. Depending on the topic the interview can be completely informal up to a psychological conversation. The main application for this type of survey is when the interviewer wants to create a relationship of trust which increases the willingness to answer the questions and to give spontaneous statements which leads to diverse insights in the way of thinking of the test person.[47]

Focus groups run evaluating and explorative discussions with 6-10 persons concerning a determined topic. They discuss under the leadership of an experienced moderator about a project, a service, an organisation or other marketing objects for several hours. The moderator has to have knowledge about the topic, objectivity as well as knowledge in group dynamics to ensure that there is no falsification of the opinions. Focus groups are, because of their explorative character, commonly used in advance of large scale surveys for a better definition of the research problem.[48]

The standardised oral survey bases on a pre-formulated questionnaire which means that form, content and order of questions is set in advance. The aim of standardised interviews is to make the results comparable and allows the aggregation of data. Standardised written surveys are built up in the same style as oral surveys. The main difference is that it is not possible to get support by the interviewer if a question is not completely clear. Therefore it is of outmost importance that the questions are unambiguously defined. All these standardised variants can be conducted by the

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[46] Cf. Homburg/Krohmer (2009), p. 254
[47] Cf. Berekoven/Eckert/Ellenrieder (1999), p. 95
[48] Cf. Lane Keller/Bliemel/Kotler (2007), p. 169

help of IT systems (standardised online surveys) which ensures a faster data evaluation and a larger range.[49]

An interesting point is that it cannot be avoided that the interviewee knows about the test situation. Just the presence of the interviewer or the fear of wrong answers can lead to a distortion of the results.[50]

The observation is a planned direct collection of conditions, properties and behaviour. Objects of observation are individuals (for example their buying behaviour) or things (like the product placement in the shelf). The observation is in the most cases not done by someone himself (self-observation) but by independent third parties (observation by others) and technical devices (machine observation). The observation is a visual and instrumental way of data collection. Facts which are perceptible by senses and non-verbal behaviour are investigated at the time of happening by people or devices (like cameras etc.).[51]

The results of an observation are independent of the willingness to provide information orally but on the willingness to become observed whereas the most important elements of an observation are:[52]

- Level of consciousness of observation:
  - In open and transparent situations the observed person is aware of the test situation, the aim and the observation object.
  - In inscrutable observations the observed person knows that he/she is in a test situation and about the observation object but not the aim of the investigation.
  - Quasi-biotic situations are when the test person only knows that he/she is in a test situation.
  - Biotic situations offer no information to the test person.
- Degree of participation of the observer: The degree of participation is in strong connection to the level of consciousness. The question is which role plays the observer in the test situation and does the observed person know about his role. In a participating observation the observer is actively involved. In a non-participating observation the observer should be unknown, but his presence should be explained to avoid mistrust. The problem at participating

[49] Cf. Homburg/Krohmer (2009), pp. 259-261
[50] Cf. Meffert/Burmann/Kirchgeorg (2012), p. 164
[51] Cf. Pesch (2010), pp. 38-39
[52] Cf. Berekoven/Eckert/Ellenrieder (1999), pp. 146-148

observations is that it is not possible to record facts in the moment of its occurrence without leaving the role of the observer.

- Degree of standardisation: There is a distinction between standardised and not standardised observation. Standardisation means to create a uniform procedure in terms of the content of observation, type of recording and the test situation. The degree of standardisation has to be decreased when the observation is still in an explorative stadium, what means that the topic to explore is relatively unknown.
- Type of perception and recording: Generally the perception of the test situation happens visually but it is for sure possible to use other senses like taste and smell. Type and extent of the records depends on the degree of standardisation. This can be done by a simple tally sheet in the case of yes or no questions, for example with a light barrier to count the number of customers in a supermarket or something else. If the observation is really unstructured (not standardised) it can be necessary to record all facts by cameras or tape-recorders which have the advantage of reproducibility.

Experiments represent a test assembly which should measure the effects of marketing variables under controlled conditions. The aim is to measure the isolated effect of marketing instruments. The major problem of an experiment is the determination and isolation of disturbing factors like measures of the competitors. One example for an experiment is the local test market. Special places are selected to test and evaluate marketing instruments as sales and discount measures, television commercials and more under real conditions.[53]

2.3.2 SWOT – Analysis

The SWOT (Strengths – Weaknesses – Opportunities – Threats) analysis figures out the resources of the own company compared to the competitors. Strengths and weaknesses are assessed especially for actual and future market situations.[54] The analysis of strengths and weaknesses requires a long-term perspective. Strictly speaking, the strengths and weaknesses analysis is only referring to the present. Practically it turned out that it is useful to do a strengths and weaknesses analysis even when the threats and opportunities in terms of future development are

[53] Cf. Broda (2002), pp. 62-63
[54] Cf. Broda (2002), p. 35

considered.[55] The SWOT-analysis compares important factors of the environment and the company by generating several strategic options. The SWOT-approach is used step by step. At first a two dimensional matrix with an environmental- and company- axis is build. Further both axes are filled with one positive and one negative field. The environmental axis is cover by opportunities and threats and the company axis with strengths and weaknesses. These fields contain the most important influencing factors which were acquired through an environmental and company analysis. The last step is to build relationships between the fields and create strategic options. Strengths and opportunities strategies are typically used if an expansion of the company is planned or for the development of new services. Strengths and threats strategies try to compensate the external risk with the internal strengths of a company. Weaknesses and opportunities strategies are used for participating on chances and minimize or eliminate the weaknesses. Weaknesses and threats strategies try to reduce the risks in the environment by decreasing internal weaknesses.[56] Figure 2-9 illustrates such a SWOT-Matrix.

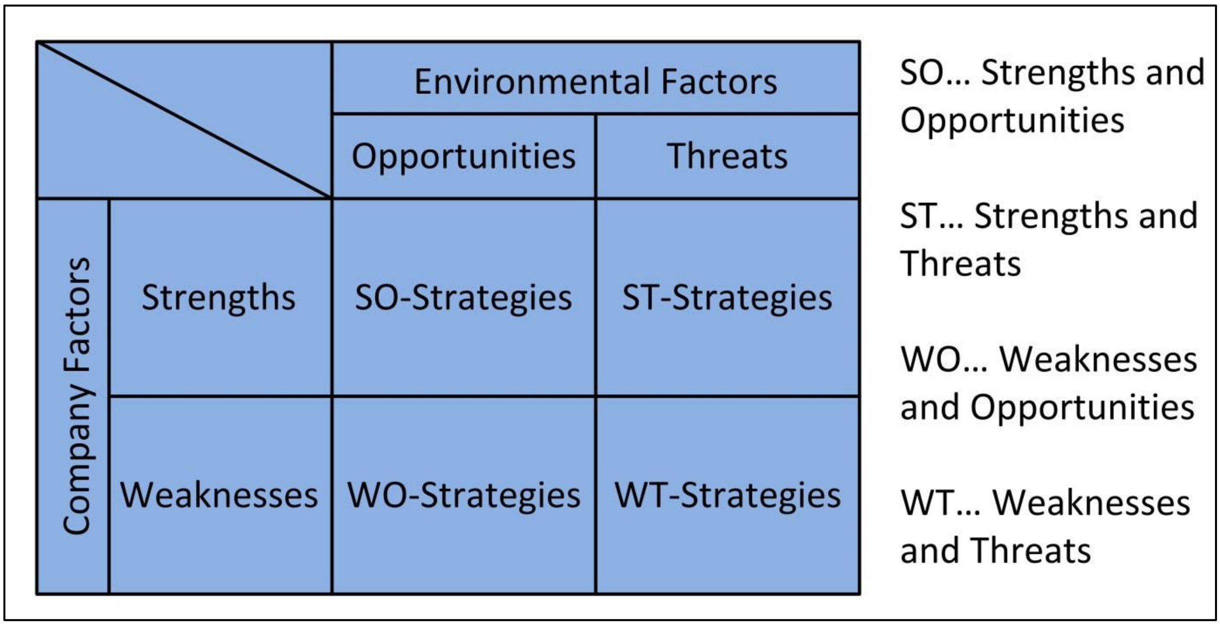

Figure 2-9: SWOT-Analysis Matrix[57]

[55] Cf. Kreikebaum (1997), p. 139
[56] Cf. Müller-Stewens/Lechner (2003), pp. 224-225
[57] Cf. Müller-Stewens/Lechner (2003), p. 225, own illustration

2.4 **Forecasting**

After analysing the initial situation the next step is forecasting. In this phase relevant factors of the market and the society as well as the effects of the own activities should be predicted to show the future potential. Of most importance are the trends on demand patterns, on competitors behaviour, in the environment, the market- and sales-development. At the end there is one major question. In which direction will the development go? [58]

There are several types of market forecasts which are separated through the following criterions:[59]

- Level of forecast: The forecasting refers to the whole market, segments of the market or on parts of the company.
- Type of dependent variable: Objects of forecasting are in most cases sales volume, turnover or market shares.
- Type of the independent variable: If data from the past is used, then we talk about development forecasts. Whereas effect forecasts predict the effects of marketing instruments used in future.
- Quantity of independent variables: Mono-causal forecasts predict the future by using one variable, multi-causal forecasts use more variables.
- Reference period of the forecast: Depending on the time frame we talk about short-, middle- or long-term forecasts
- Influencing parameters: The development of market relevant parameters is determined by external factors which influence the forecasting result. Therefore there is a distinction between seasonal-, economic-, and growth-forecasts.
- Reference object: Market forecasts refer to future behaviour of market participants. It can be distinguished between consumer-, competitor-, marketing intermediary-, and environment-forecasts.
- Type of measurement: Quantitative methods use a mathematical-statistic approach. Qualitative methods have no formal logarithms for finding a solution.

The process of forecasting can be divided in individual steps as shown in Figure 2-10.

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[58] Cf. Meffert/Burmann/Kirchgeorg (2012), p. 21
[59] Cf. Bruhn (2012), pp. 115-116

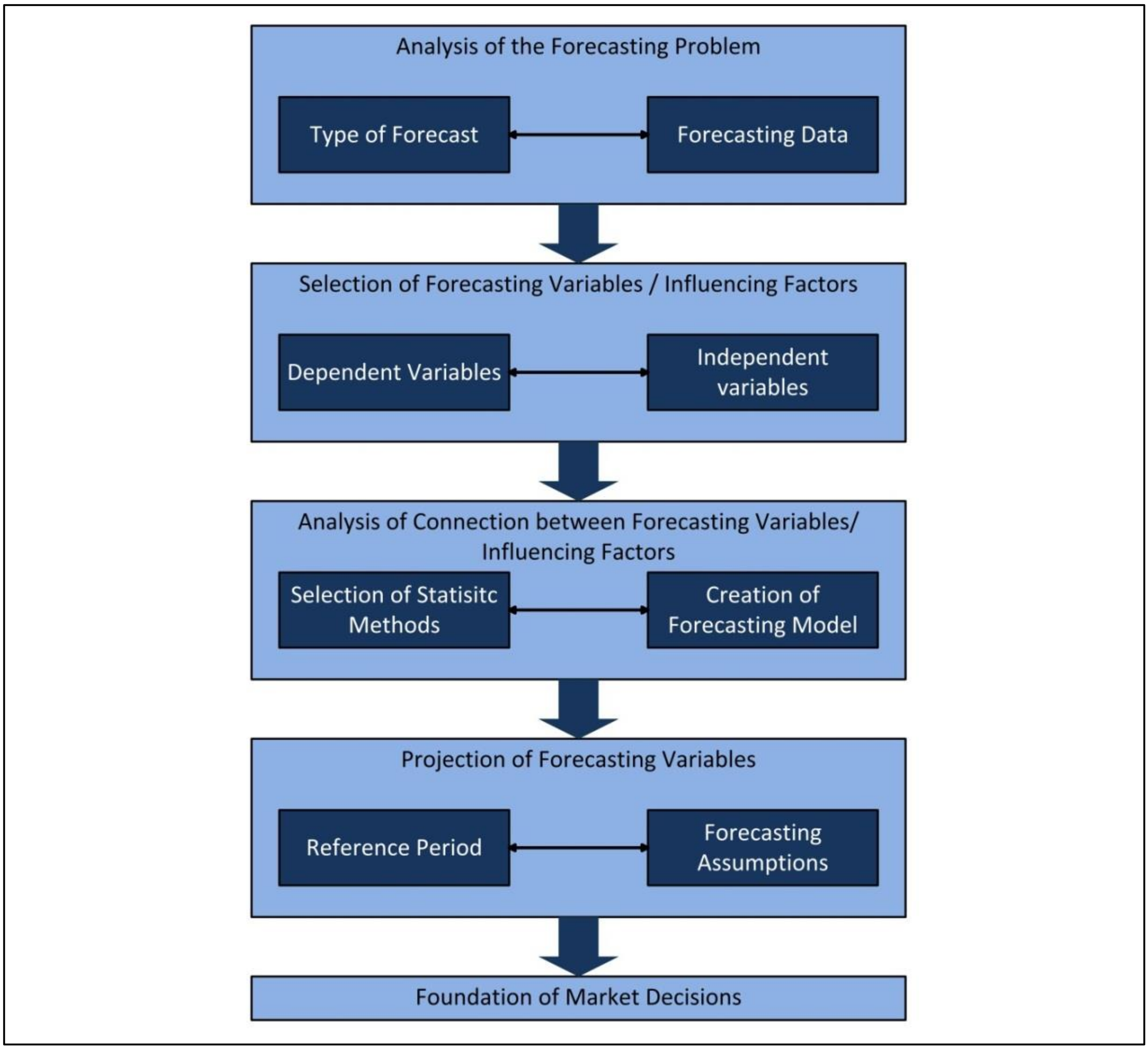

Figure 2-10: Process of Forecasting[60]

At the beginning of the forecasting process is the analysis of the problem. It determines the type of forecast (short-, middle-, long-term) and identifies which data is already available or can be used for the solution of the problem. If the type of forecasting is determined the next step would be to select the forecasting variables and influencing factors. In this phase the forecasting variables (dependent variables) and the influencing variables (independent variables) are indicated. The evaluation of the connection between forecasting variables and influencing factors leads to the creation of a forecasting model. The further projection of the variables is the basis for the market decision.[61]

[60] Cf. Bruhn (2012), p. 117, own illustration
[61] Cf. Bruhn (2012), p. 117

2.4.1 Quantitative Forecasting Methods

Quantitative forecasting methods include the projection of forecasting variable on basis of mathematical functions. There is a general distinction between development forecasts and causal forecasts.[62]

2.4.1.1 Development Forecasts

Development forecasts assume that past values of the forecasting variables can be the basis for predictions. The two major models are the trend- and the indicator-prediction.[63]

The trend forecast is done in the following five steps:[64]

- Step 1: The past values of the forecasting variables are listed and graphically represented if necessary.
- Step 2: The type of the function is chosen by the observation of the values of the forecasting variable. Basically there are mathematical functions like the linear trend, exponential trend and the logistic trend. A linear trend is used when a stable development of the market is expected. The exponential trend is used for markets with strong growth impulses whereas the logistic trend is chosen when decreasing growth rates are expected. Figure 2-11 gives an overview of the different trend functions.

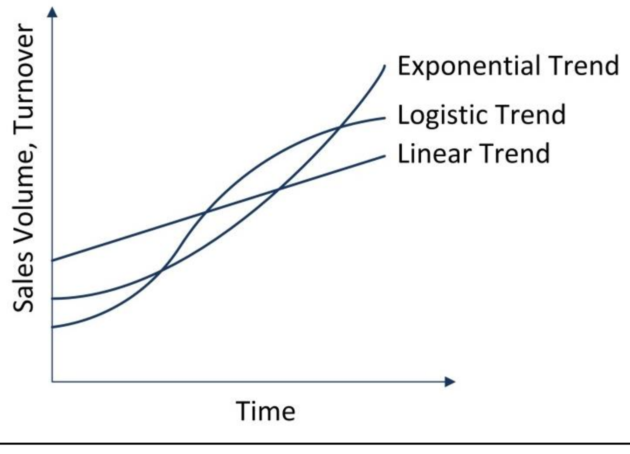

Figure 2-11: Trend Functions[65]

[62] Cf. Nieschlag/Dichtl/Hörschgen (1997), p. 836
[63] Cf. Berekoven/Eckert/Ellenrieder (1999), pp. 258-259
[64] Cf. Bruhn (2012), p. 118
[65] Cf. Bruhn (2012), p. 119, own illustration

- Step 3: If the decision on the type of the function is made the parameters of the function are calculated.
- Step 4. If the trend function is calculated, then a dimension for the assessment of the suitability of the calculated function is necessary. One example is the correlation coefficient which shows the degree of the connection between two variables.
- Step 5: When the function is suitable, the next step is the projection of the forecast variable.

The major advantage of trend predictions is that they are pretty easy to calculate. Problems occur in the selection of the reference period, change of reference period, selection of the trend function and the fact that it is not always the case that the prediction of the future is possible out of past data.[66]

Indicator forecast are the second method. In this case not values from the past are the basis for the prediction but the development of an indicator. The indicator has to have a strong relation, a high correlation to the forecasting variable. The future market development should be reproduced as good as possible. One example is the prediction of the sales of car tyres on basis of the sold vehicles in a certain time period.[67]

The starting point of an indicator prediction is to choose an appropriate lead indicator. The main idea is to find a time series which has preferably the same development as the time series which is to predict. It is important that the time series to predict has a time lag to the series which is the lead indicator. If this is the case it is possible to draw a conclusion out of it.[68]

The procedure how such an indicator prediction is done is shown in Figure 2-12.

[66] Cf. Pepels (1995), pp. 411-413
[67] Cf. Pesch (2010), p. 58
[68] Cf. Berndt (1996), p. 266

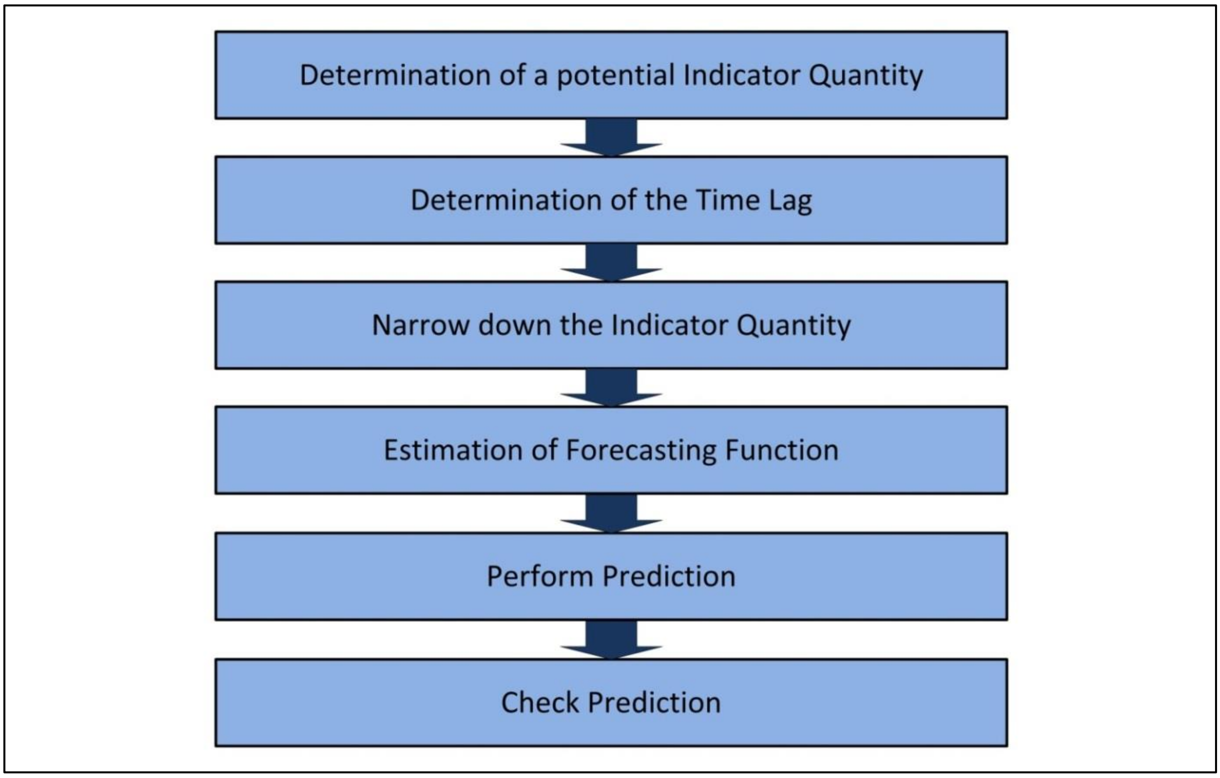

Figure 2-12: Procedure of an Indicator Prediction[69]

The determination of potential indicator quantity is the first step which defines the indicators with a strong relation to the forecasting variable. After the time lag is set the indicator quantity is narrowed down by choosing the indicator(s) with the strongest relation to the forecasting variable and an adequate time lag. Then the forecasting function is estimated and the prediction is made. The last step is to check the estimation and results for plausibility.[70]

2.4.1.2 Causal Forecasts

Causal forecasts investigate the connection between a dependent and an independent variable. The goal is to measure the future development of performance indicators (like turnover, sales volume) in comparison to the use of marketing instruments.[71]

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[69] Cf. Niederhübner (2005), p. 205, own illustration
[70] Cf. Niederhübner (2005), pp. 205-206
[71] Cf. Pfaff (2004), p. 224

Is just the influence of one marketing mix factor measured then this is called a mono instrumental model, are more factors considered the same time then it is called a poly-instrumental model.[72]

Figure 2-13 gives an example how such a forecast can look like. The money spent for promotion is used to forecast the turnover of a company.

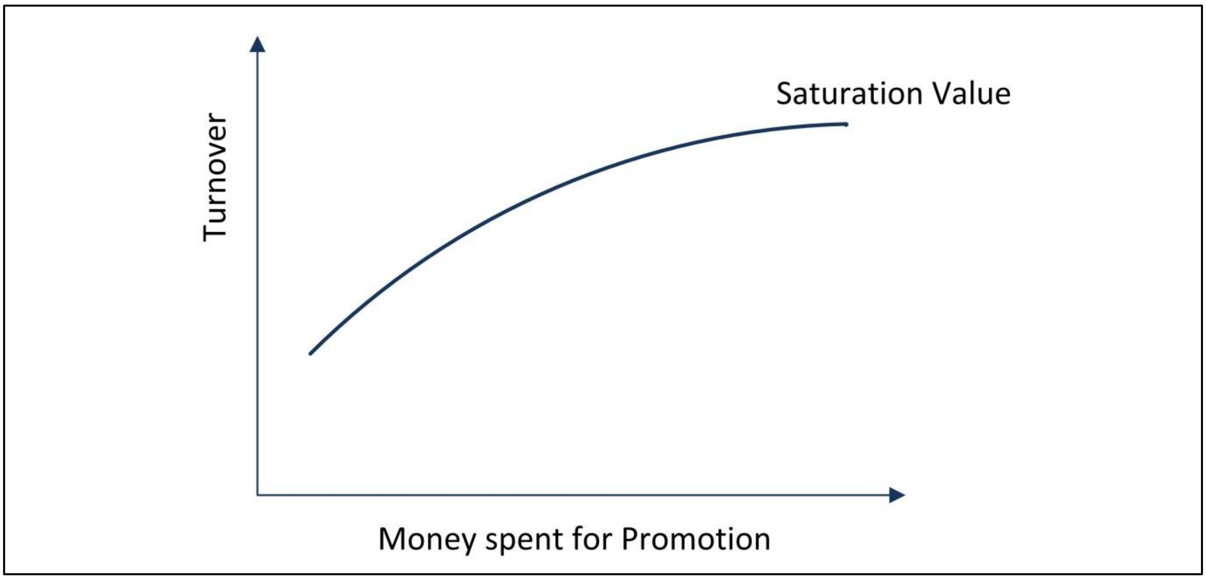

Figure 2-13: Example of an Effect Forecast[73]

2.4.2 Qualitative Forecasting Methods

Qualitative methods use subjective, intuitive methods like surveys and expert opinions. These methods are also called heuristic forecasts. Qualitative forecasts are very important in practical use because they are easy to apply, fast and cheap. The most frequent used methods are expert opinions, the Delphi-method and the scenario technique.[74]

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[72] Cf. Koch (2010), p. 262
[73] Cf. Pfaff (2004), p. 124, own illustration
[74] Cf. Koch (2010), p. 262

2.4.2.1 Experts Opinions

To ask experts about their experiences and opinions is a tried and tested approach to get information from competent sources. Free and unstructured interviews can deliver and expose interesting aspects of the problem whereas structured interviews make it easier to compare the answers.[75]

Expert interviews can be an individual or group discussion. A group discussion can lead to a general compromise among the experts. One threat can be that they influence each other to much and some participants dominate the others. To avoid this risks the Delphi method can be applied.[76]

The classical approach to conduct a Delphi-method is as follows:[77]

- Definition of the overall problem and identification of criteria which are necessary for the assessment through experts. This step can be done by the team which monitors the Delphi-method as well as by asking the experts.
- Development of a standardised questionnaire. This questionnaire is required to ask the experts anonymously concerning the topics of interest.
- Preparation of the results from the questionnaire by the monitoring team and anonymous feedback to the participants.
- Repeat the questionnaire on basis of the gained knowledge till a predefined stop criterion is reached.

Empirical testing showed that there should be at least three rounds of questioning to get a substantiated result.[78]

2.4.2.2 Scenario Technique

The scenario technique considers especially uncertainties in the future by developing several scenarios for the research area. There is on the one hand the description of a possible future situation as well as the development to reach this situation. The first step is to analyse and define a reference area for which the scenario is created. This can be the whole company or segments out of it. In the second phase it is important

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[75] Cf. Berekoven/Eckert/Ellenrieder (1999), p. 269
[76] ibidem
[77] Cf. Häder (2009), p. 24
[78] Cf. Berekoven/Eckert/Ellenrieder (1999), pp. 269-270

to identify the environmental factors which influence the reference area. Further the environmental factors have to be analysed how they influence and affect the reference. In the third phase assumptions concerning the development are merged and used for the creation of rough scenarios. Then it has to be selected which of this rough scenarios should be investigated more in detail. The fourth step is the elaboration of the rough scenarios and eventually the investigation of potential disturbing factors. Important is to figure out which factors influence the reference area, how much they influence the reference area, which connection is between these factors, which factors are crucial for the overall system and which development is possible for these factors. At the end there should be a potpourri of scenarios. Two contrary scenarios span the scenario funnel as shown in Figure 2-14.[79]

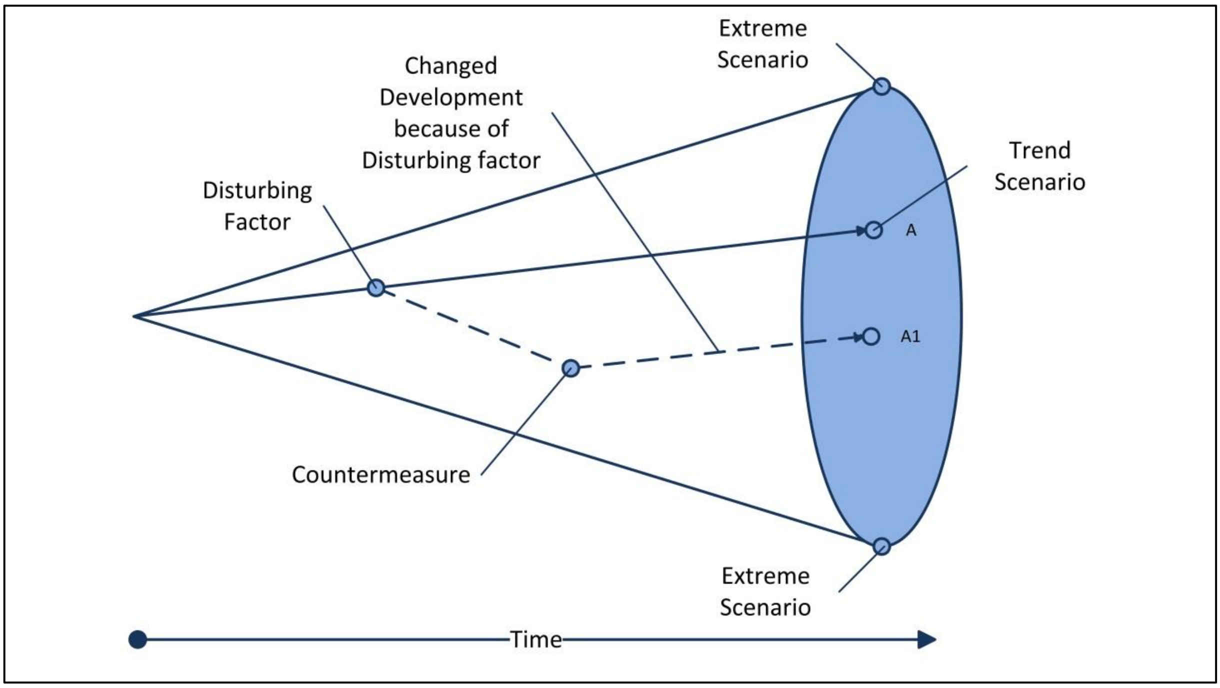

Figure 2-14: Scenario Funnel[80]

The boundaries of the funnel show the potential for development. Trend scenarios have to be always in between these boundaries. A disturbing factor could have a negative influence on the development and requires countermeasures. Summarized scenarios are artificial models of the future, based on assumptions. The longer the time frame, the more scenarios can be found.[81]

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[79] Cf. Götze/Henselmann (2001), pp. 395-396
[80] Cf. Müller-Stewens/Lechner (2003), p. 210, own illustration
[81] Cf. Müller-Stewens/Lechner (2003), pp. 210-211

3 Processes and Manufacturing Methods

The following chapter provides an overview of the basic methods for manufacturing of car body parts.

3.1 Deep Drawing

Deep drawing is one of the most important manufacturing methods for producing sheet metal parts with three-dimensional geometry. It is mainly used in serial production like the automotive – and packaging-industry as well as in low volume production, for example in the aircraft industry. It is of outmost importance to control the material flow, to choose the proper raw material and to apply the right force onto the blank holder to achieve the desired results.[82]

The process involves forming by tensile and compressive forces of a blank to a hollow body. The procedure of a deep drawing process starts with placing the tailored blank on the die. In the next step the blank holder presses the blank firmly onto the die. The drawing punch draws the blank through the opening of the die and reduces the external diameter until it has been completely formed into a hollow body. In the last step the drawing punch moves back to its initial position and wipes off the blank. [83]

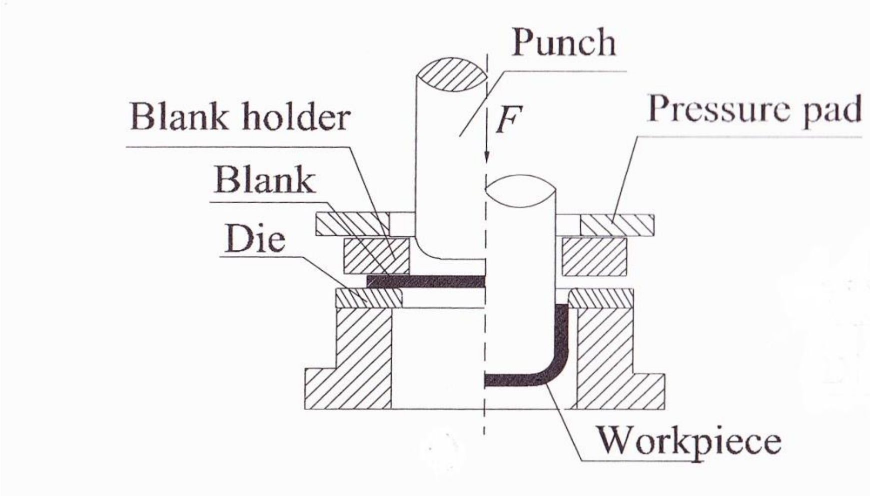

Figure 3-1: Deep Drawing Process: Pure Drawing[84]

[82] Cf. Klocke/König (2006), p. 323
[83] ibidem
[84] Boljanovic (2004), p. 70

Deep drawing is a very popular process because of the rapid cycle times and the ability to produce complex axisymmetric- and certain non-axisymmetric-geometries with a few operations. There is a distinction between two deep drawing processes. First the deep drawing without a reduction in the thickness of the work piece material (pure drawing) as shown in Figure 3-1 and second deep drawing with a reduction in the thickness of the work piece material (ironing) as shown in Figure 3-2.[85]

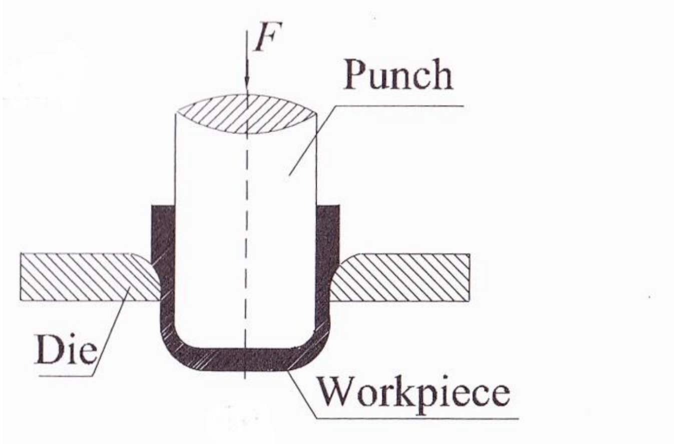

Figure 3-2: Deep Drawing Process: Ironing[86]

3.2 Stretch Forming

Stretch forming is a metal shape process used to form parts from nickel, steel, aluminium and titanium alloys which are difficult to form using other processes. Typically the method is used for producing automotive door panels and parts for the aerospace industry. With stretch forming it is not possible to produce sharp-cornered shapes.[87]

Stretch Forming is a process in which the sheet metal is intentionally stretched and simultaneously bent in order to achieve shape change. The work piece is gripped by one or more jaws on each end and further stretched and bent over a positive die. The metal is stressed in tension above its yield point. This leads to a plastic deformation when the tension loading is released. Due to the fact that the sheet metal is stretched and bent the springback in the part is relatively little.[88]

[85] Cf. Boljanovic (2004), pp. 69-70
[86] Cf. Boljanovic (2004), p. 70
[87] Cf. Youssef/El-Hofy/Ahmed (2012), p. 270
[88] Cf. Groover (2010), p. 471

Two methods are used in stretch forming:[89]

- Form Block Method: Every end of the sheet metal is held in tension by an adjustable gripper. The gripper is moved to stretch the sheet metal over a form block. This block is moved hydraulically by a piston to achieve the desired shape.
- Mating Die Method: The blank is held in tension by moveable grippers. There are two actions during the process. At first the grippers stretch the work part by a predetermined amount to approximately 2 percent elongation over the form block. Second the punch moves downwards onto the blank to form the work part by pressing the metal against the dies.

Figure 3-3 and Figure 3-4 show schematic illustrations of these stretch forming processes.

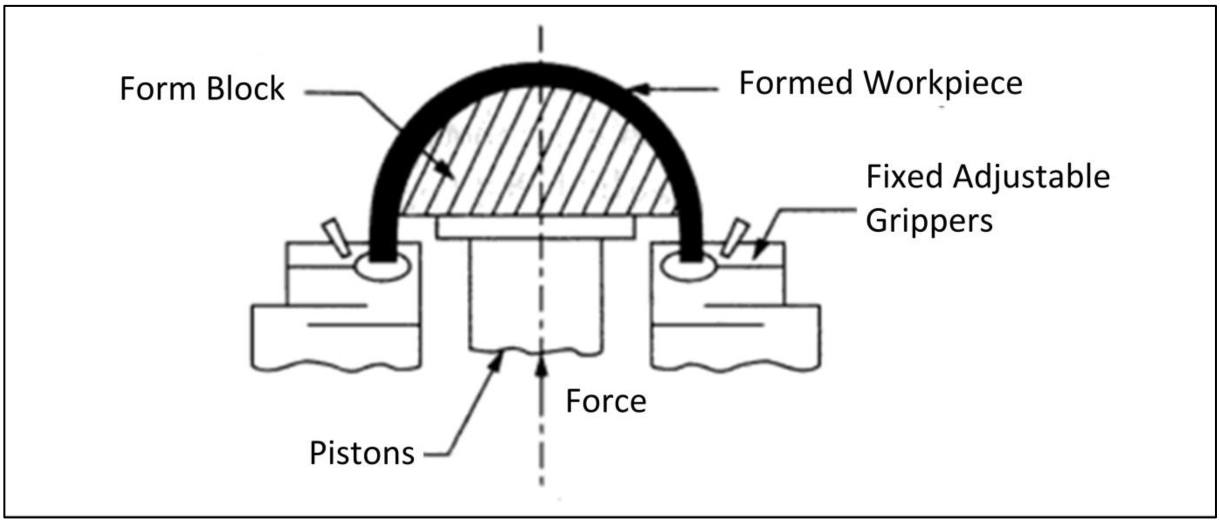

Figure 3-3: Stretch Forming - Form Block Method[90]

[89] Cf. Boljanovic (2004), pp. 85-87
[90] Gowhri/Hariharan/Suresh-Babu (2008), p. 348

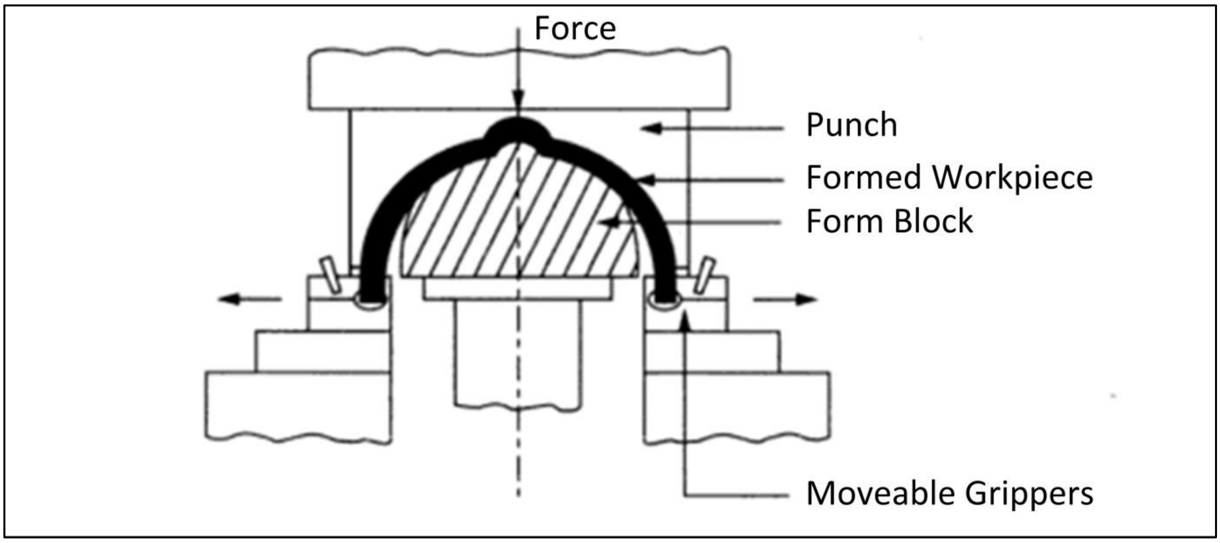

Figure 3-4: Stretch Forming - Mating Die Method[91]

3.3 Press Hardening

Press hardening is a method to produce ultra-high-strength sheet metal components with complex geometries. It combines the forming process with a heat treatment. The ultimate tensile strength (R_m) of the manufactured parts is above 1500 Megapascal (MPa). Press hardened parts are mainly used in automotive industry for crash-relevant parts like B-pillars or side-impact beams. An appropriate sheet metal material is boron alloyed steel.[92]

Press hardening can basically be distinguished in two different processes:[93]

- Direct Press Hardening: The tailored blank is heated up to approximately 930°C and then simultaneously formed and cooled down by a rate of more than 27 Kelvin per second. This is the reason for building a martensitic structure. The final cutting of the hardened blank is usually done with laser technology.
- Indirect Press Hardening: In this case the raw blank is cold formed and then cut to the final geometry. After these steps the blank is heated up to approximately 910°C and cooled down in a calibration tool at the same rate as used in direct press hardening. Indirect press hardening has some technological and economic advantages compared with direct press

[91] Gowhri/Hariharan/Suresh-Babu (2008), p. 348
[92] Cf. Doege/Behrens (2010), p. 365
[93] Cf. Dick et al. (2008), pp. 42-43

hardening. The reason is the cold forming process at the beginning. That makes it possible to use the conventional press lines and avoids cost- and time-intensive laser technology for cutting. The disadvantage is that the change of shape due to the hardening process has to be considered for parts with critical tolerances and the cycle times are slower than for the direct press hardening process.

Figure 3-5 and Figure 3-6 show a scheme of direct/indirect press hardening.

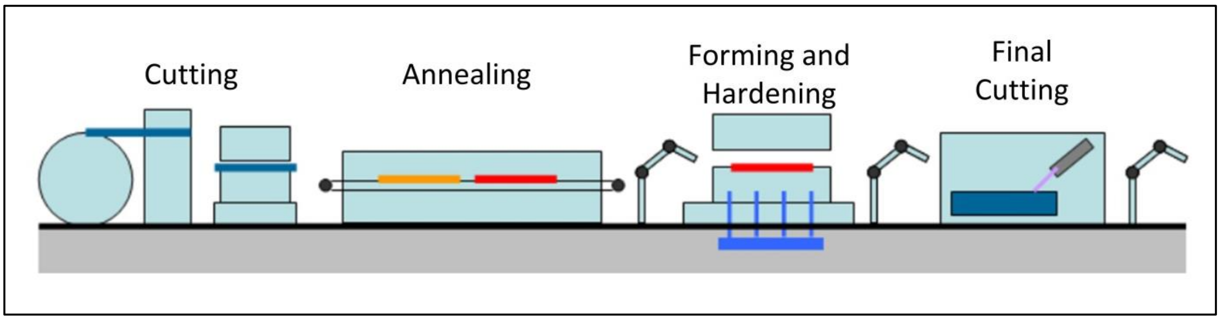

Figure 3-5: Direct Press Hardening[94]

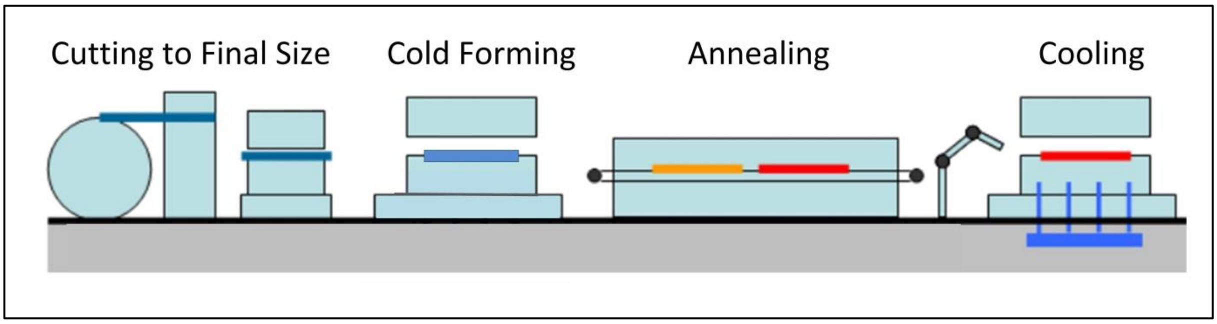

Figure 3-6: Indirect Press Hardening[95]

3.4 Hydroforming

Hydroforming is a manufacturing process using fluid pressure to shape metallic blanks. The blanks are sheet metals or tubular sections. If sheet metal blanks are the initial material then the process is called sheet metal hydroforming. The second process is called tube hydroforming.[96]

[94] Cf. Neugebauer et al. (2012), p. 2
[95] Cf. Dick et al. (2008), p. 42, own illustration
[96] Cf. Singh (2003), p. 1

3.4.1 Sheet Metal Hydroforming

Basically the approach for sheet metal hydroforming is to press a smooth large-area section of sheet onto a water chamber clamped down by a specially designed blank holder.[97]

A typical process is the hydrodynamic deep drawing (HDD). In this case the die cavity is filled with oil or other liquids and the punch pushes the blank into it. That implies a high pressure which makes it possible to press the sheet metal tightly onto the punch. The use of liquid increases the limiting drawing ratio value of sheet metal and further improves the part quality. The utilization of the liquid as a punch, draw die or an assisting way to improve sheet formability divides the process into active and passive sheet hydroforming.[98]

Figure 3-7 shows a hydrodynamic deep drawing application.

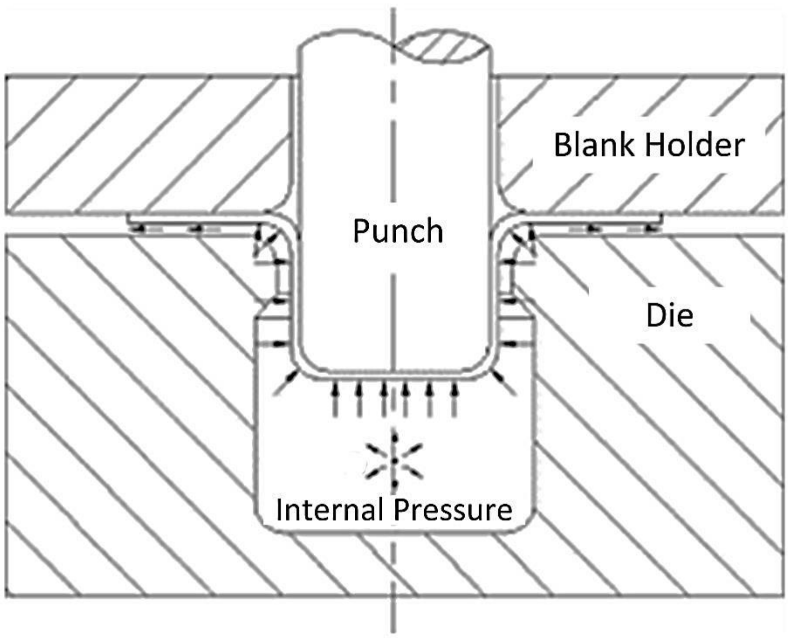

Figure 3-7: Hydrodynamic Deep Drawing[99]

[97] Cf. Tschaetsch (2006), p. 174
[98] Cf. Lang et al. (2004), pp. 165-166
[99] Lang et al. (2004), p. 166

3.4.2 Tube Hydroforming

The approach for tube hydroforming is the same as for sheet metal hydroforming. The tube is formed with internal fluid pressure that expands the tube walls conforming to a die shape. The process starts by placing the tube in a press and filling it with fluid. The next step is to close the tool and pump fluid with high pressure inside the tube to force the tube walls to expand, following the press cavity shape. The main advantage of tube hydroforming compared to other stamping-based stretch-forming processes is that hydroforming provides uniform pressure to all tube areas. That makes it possible to use lower formability materials and the process is easier to control. Another positive factor is that tube hydroforming allows weight reduction and cost reduction because it reduces the quantity of parts and production steps for one component. This enables the forming of lightweight materials such as aluminium, magnesium and metal matrix composites which is a main requirement to be used in automotive industry.[100]

Overall the process can be summarized in three steps, filling, forming and calibrating.[101] Figure 3-8 shows a scheme of the tube hydroforming.

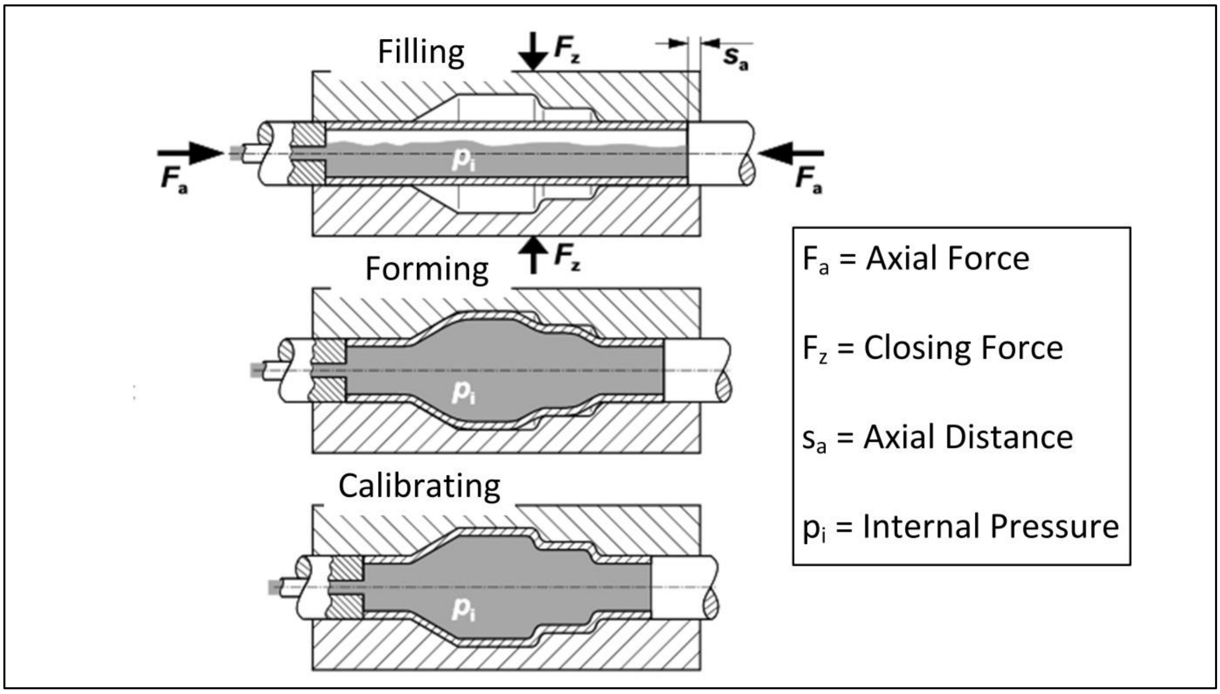

Figure 3-8: Tube Hydroforming[102]

[100] Cf. Omar (2011), pp. 80-81
[101] Cf. Klocke/König (2006), p. 425
[102] Cf. Klocke/König (2006), p. 426

3.5 Die Casting

Die casting uses permanent metal moulds in which the liquid alloy is either poured directly or injected into a die under pressure. This makes it possible to distinguish into gravity die casting and pressure die casting. The use of permanent moulds makes these processes suitable for high volume production.[103]

3.5.1 Gravity Die Casting

The molten metal is poured under gravity into a permanent metal die. It is a very simple process and widely used in aluminium casting due to the metallurgical quality and complexity of castings that can be made. There is no necessity for powerful closing forces to hold the mould halves together as in pressure die casting. The dies are normally opened and closed hydraulically.[104]

Figure 3-9 shows the basic scheme of gravity die casting.

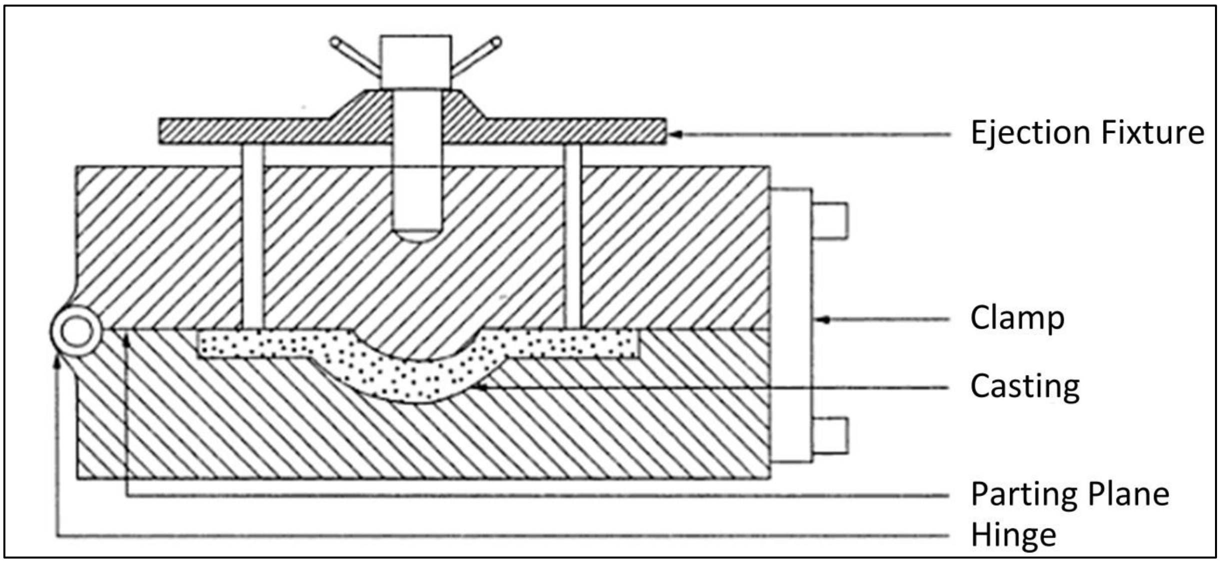

Figure 3-9: Gravity Die Casting[105]

[103] Cf. Beeley (2001), p. 591
[104] Cf. Brown (1999), pp. 124-125
[105] Gowhri/Hariharan/Suresh-Babu (2008), p. 77

3.5.2 Low-Pressure Die Casting

This process is used for high volume, high integrity castings in alloys ranging from zinc, magnesium, copper to aluminium. Aluminium has become the most widely used material because of the increased popularity of lightweight design in automotive industry.[106]

The principle of low-pressure die casting works as follows. A metal die is placed above a furnace which heats up the metal. A so called riser tube which extends from the bottom of die into the molten metal makes it possible to push the metal up by insufflating air or inert gas under low pressure. The metal enters the cavity with low turbulences and the air is escaping through the vents and the parting lines of the die. After the solidification of the metal the air pressure is released and the still molten metal flews back into the furnace. After some cooling time the die can be opened and the casting can be taken out. Typical applications are automotive parts like wheels, cylinder heads, blocks, manifolds and housings. [107]

Figure 3-10 shows the process of low pressure die casting.

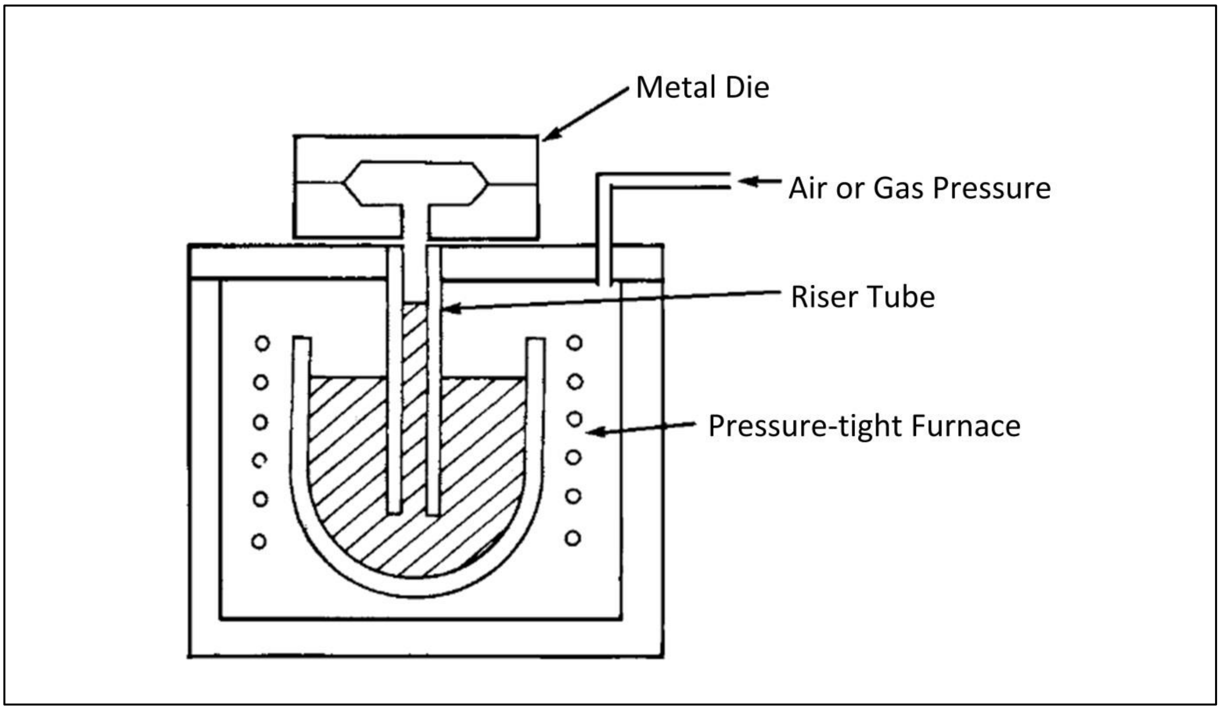

Figure 3-10: Principle of Low-Pressure Die Casting[108]

[106] Cf. Woycik (2008), p. 700
[107] Cf. Brown (1999), p. 118-119
[108] Cf. Campbell (2011), p. 961

3.5.3 High-Pressure Die Casting

High-pressure die casting is characterized by the use of hydraulic energy to rapidly fill the metal die. The functions of the die are to absorb the stresses of injection, to dissipate the heat contained in the molten metal and to allow the removal of the shaped part in preparation of the next cycle. The used alloys for high-pressure die casting are aluminium-, zinc-, magnesium-, and copper-base alloys. The main categories are the hot chamber process and the cold chamber process. These processes have been improved in recent years to produce high-integrity die castings with mechanical properties which allow producing structural and safety applications in several industries.[109]

Hot chamber machines are mainly used for casting of zinc- and magnesium-alloys. They are unsuitable for aluminium and other alloys of higher melting temperature because they give rise to contamination with iron due to contact of the molten alloy with the walls of the chamber.[110]

The hot chamber process shown in Figure 3-11 works as follows. At first (1) die is closed and the gooseneck is filled with molten metal. The pot is heated and can also serve as a melting furnace if a central melting facility is not used. In the next step (2) the plunger the liquid alloy through gooseneck and nozzle into the die cavity where the alloy is held under pressure until it solidifies. Further (3) the plunger moves back while pulling the molten metal back. The die opens and the ejector pins push the casting out of the moveable die half.[111]

[109] Cf. Butler (2008), p. 715
[110] Cf. Beeley (2001), p. 597
[111] Cf. Goodwin (2008), pp. 719-720

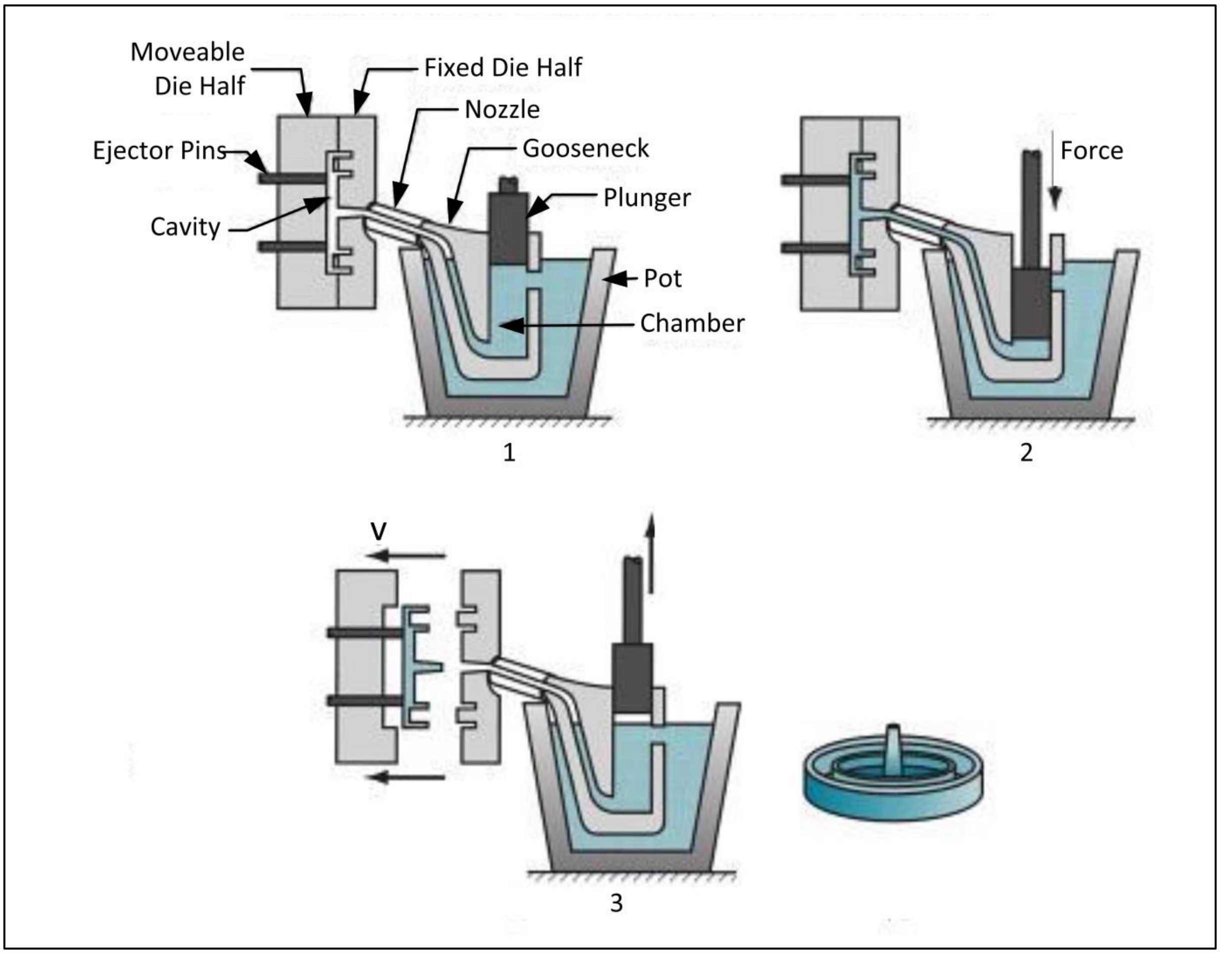

Figure 3-11: Hot Chamber Die Casting Process[112]

The cold chamber die casting is used for higher-melting-point alloys like aluminium and magnesium. Compared to the hot chamber process the cold chamber is located outside of the furnace which makes it necessary to transport the molten metal from the furnace to the chamber. This is usually done with a ladle mechanism which can be manually or automatically operated.[113]

The cold chamber process illustrated in Figure 3-12 starts (1) with loading the metal for a single shot into a cylindrical shot chamber. Then (2) the ram pushes the metal into the die and the entire injection operation is completed in a few seconds so that iron contamination is not possible. After solidification (3) the casting is pushed out by the ejector pins.[114]

[112] Cf. Groover (2010), p. 240
[113] Cf. McInerney II (2008), p. 724
[114] Cf. Beeley (2001), pp. 597-598

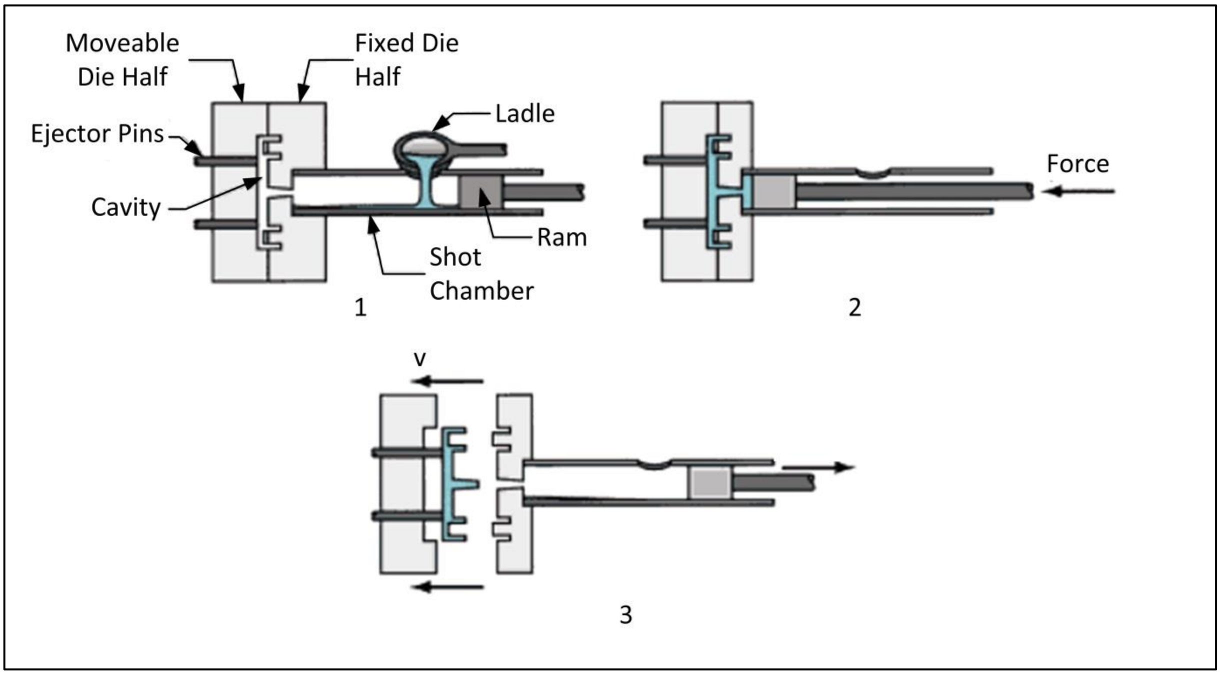

Figure 3-12: Cold Chamber Die Casting Process[115]

Summarized a conventional hot chamber process resembles a cold chamber process pretty much except the injection section. A major difference is the cycle time. Hot chamber machines allow much faster cycles than cold chamber machines. There are two reasons for that. Firstly in the hot chamber machine the metal is readily available to fill the shot chamber after each cycle whereas in a cold chamber machine the metal must be ladled into the shot chamber. Secondly the melting point of used alloys in the hot chamber process is lower which leads to less heat extraction to solidify the metal before ejection.[116]

[115] Cf. Groover (2010), p. 241
[116] Cf. Goodwin (2008), p. 720

4 Automotive Market Analysis

The first step of the practical part is to investigate the development of the automotive industry in India, China and Europe. The change in the demand for passenger cars is one of the main indicators which further build the basis to estimate the influence on the business of Uddeholms AB.

4.1 Affordability Differences

One of the most important questions is which type of car and technology people can afford in emerging markets. Therefore it is necessary to figure out the different levels of affordability by comparing the development of the gross domestic product (GDP) and the purchasing power.

GDP is the monetary value of all the finished goods and services produced within a country's borders in a given time period, though GDP is usually calculated on an annual basis. The GDP measures the value of all goods and services used by the factors of production, land, labor and capital.[117]

The gross domestic product is distinguished in nominal and real gross domestic product. The real gross domestic product is the nominal gross domestic product after accounting for inflation. Comparing the real gross domestic product from year to year shows the amount an economy has grown or shrunk and how this actually affects the economy. As example when the nominal gross domestic product has grown by 10 percent and the inflation is 3 percent, the real gross domestic product is 7 percent.[118]

In Figure 4-1 the past development and forecast for the real gross domestic product growth of China, India, and the European Union is shown.

[117] Cf. Tainer (2006), p. 23
[118] Cf. Financial Dictionary (2013), www.financial-dictionary.thefreedictionary.com/Real+GDP, accessed July 10th 2013

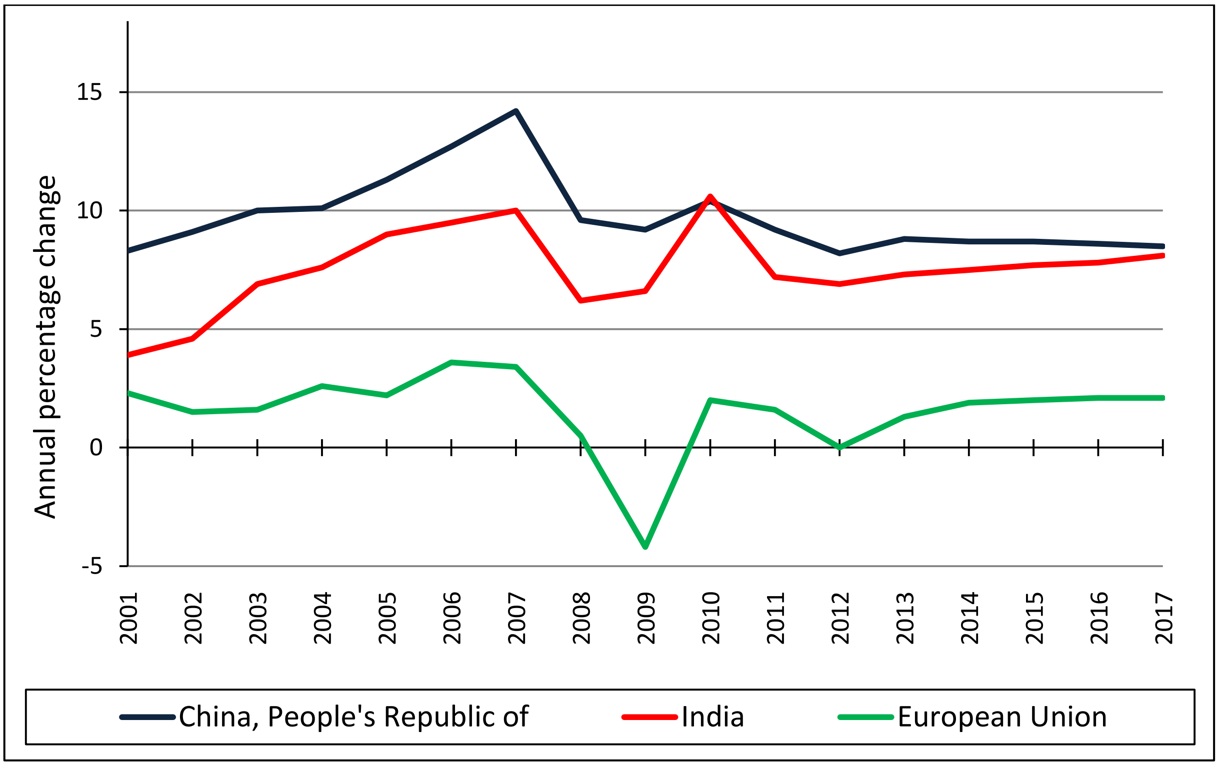

Figure 4-1: Real GDP Growth[119]

The annual GDP growth rate for the European Union, China and India is expected to be relatively stable in the next five years, whereas China and India with approximately 8% have a significantly higher rate compared to around 2% in the European Union.

In comparison to the real GDP growth, the GDP based on purchasing power parity (PPP) per capita allows much better to draw inferences about the living standard of a countries population.

“A purchasing power parity is a price relative which measures the number of units of country B currency that are needed in country B to purchase the same quantity of an individual good or service as 1 unit of country A’s currency will purchase in country A.”[120]

“To compare living standards across countries, PPP exchange rates are constructed by comparing the national prices for a large basket of goods and services. These

[119] International Monetary Found (2012), Dataset, own illustration
[120] Organisation for Economic Co-operation and Development, www.stats.oecd.org/glossary/detail.asp?ID=2204, accessed April 9th 2013

rates are used to translate different currencies into a common currency to measure the purchasing power of per capita income in different countries."[121]

Figure 4-2 shows that the gap between China and India in this case is much bigger than in the chart before. China will reach a GDP per capita based on PPP of around 15000 international dollars whereas India will scratch at the 6000 international dollar limit in 2017.

"An international dollar would buy in the cited country a comparable amount of goods and services a US dollar would buy in the United States."[122]

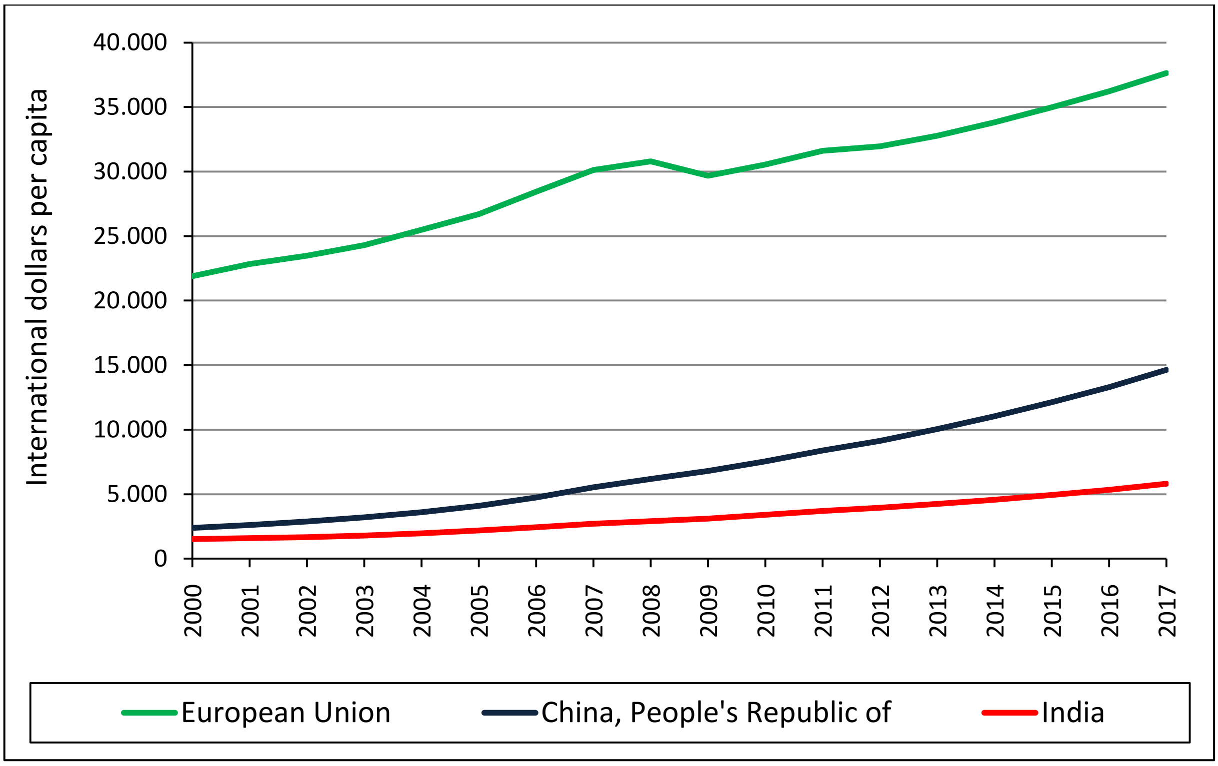

Figure 4-2: GDP based on Purchasing Power Parity per Capita[123]

The gap between Europe, India and China in Figure 4-2 influences in the end the purchasing power of the inhabitants. As the price for a product has to fit to the current market situation, this further establishes constraints for the utilized technology.

Affordability remains as the significant factor when talking about vehicle sales. The average price for a car in India and China exceeds the disposable personal income (DPI) multiple times which is shown in Figure 4-3. An example should explain this

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[121] Lafrance/Schembri (2002), p. 1
[122] Worldbank (2013), www.data.worldbank.org/about/faq/specific-data-series, accessed 16th July 2013
[123] International Monetary Found (2012), Dataset, own illustration

circumstance and underline the affordability issue. The average price for a two wheeler in India is about 900 United States Dollar (USD) which leads to a market share of more than 75 percent on the whole Indian motor vehicle market (motor vehicle market includes two wheelers, three wheelers, passenger cars and commercial vehicles). That is an obvious explanation why the car ownership level (cars per 1000 inhabitants) in emerging countries still is far behind Europe.[124]

"Disposable personal income equals personal income minus personal taxes-income taxes, excise and real estate taxes on personal property, and other personal taxes. DPI is the income that individuals have at their disposal for spending or saving. The sum of consumption spending plus saving must equal disposable personal income."[125]

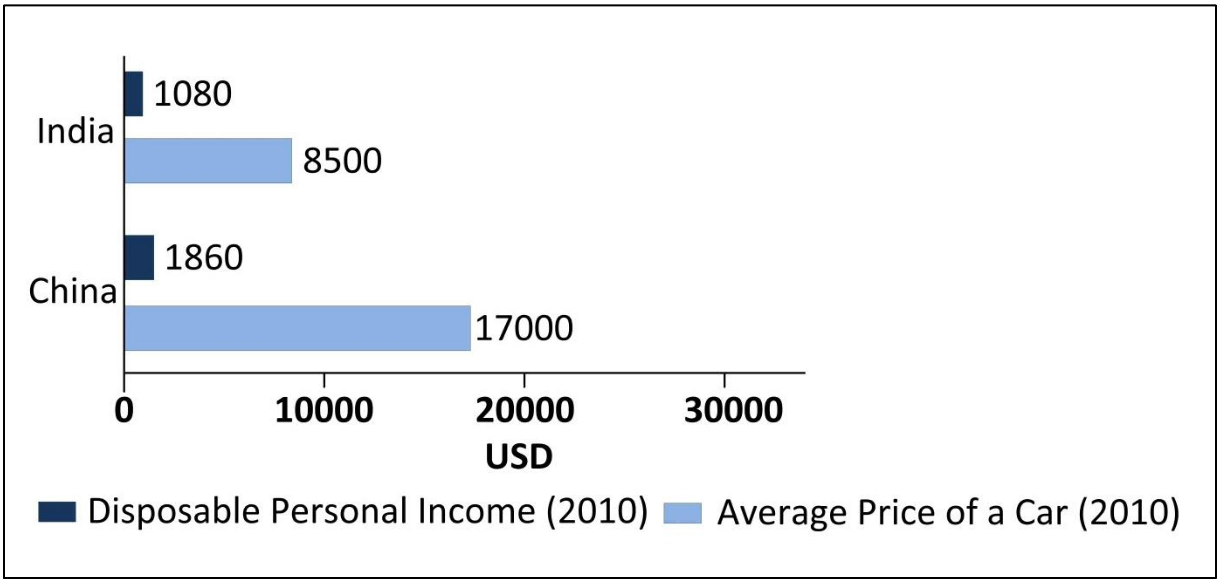

Figure 4-3: Vehicle Affordability[126]

Car manufacturers have to meet the requirements set by the market. The technology level and production volume (economies of scale effect) have the highest influence on the affordability. The connection between these factors is shown in Figure 4-4. A technology level (by the car itself) which allows a cheap production and a high production volume lead in the end to an affordable price.[127]

124 Cf. Becker/Nagporewalla (2010), p. 8
125 Boyes/Melvin (2011), p. 103
126 Becker/Nagporewalla (2010), p.9, own illustration
127 ibidem

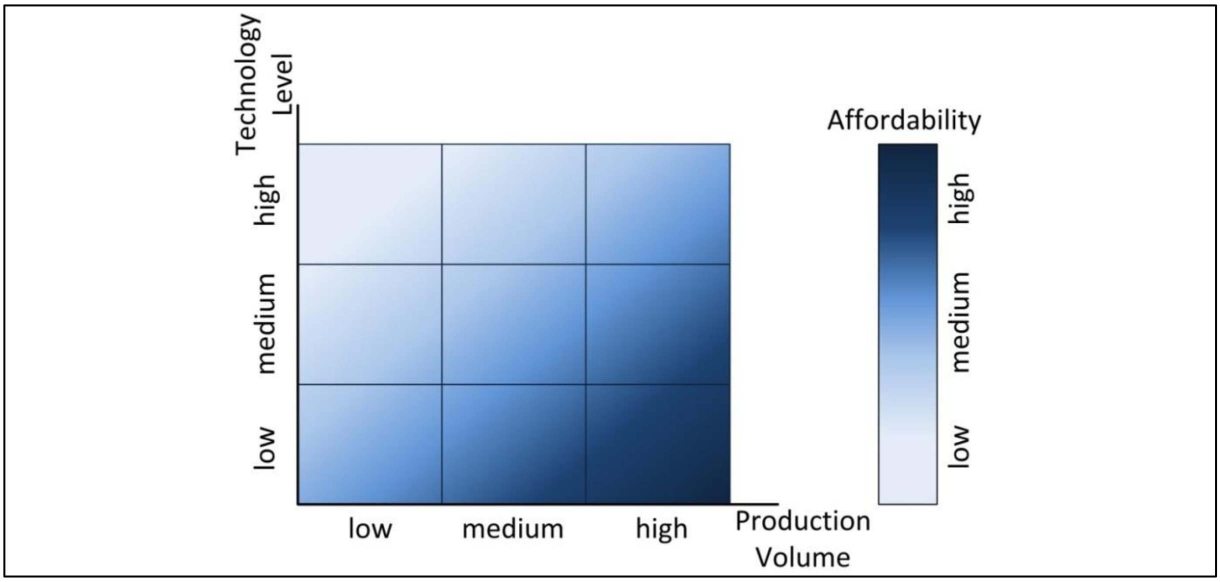

Figure 4-4: Affordability Map

The crux of the matter in emerging markets is the budget. It is just the question if you can buy a car and not if it has a unique design or some special additional equipment. First of all it serves as a mean of transportation. The following chart shows very well how people make their decisions in connection to the car segment. For the small car segment (A/B, purchase price ranked first) and also for the mid-class segment (C/D, purchase price ranked third) the price is very important factor.[128]

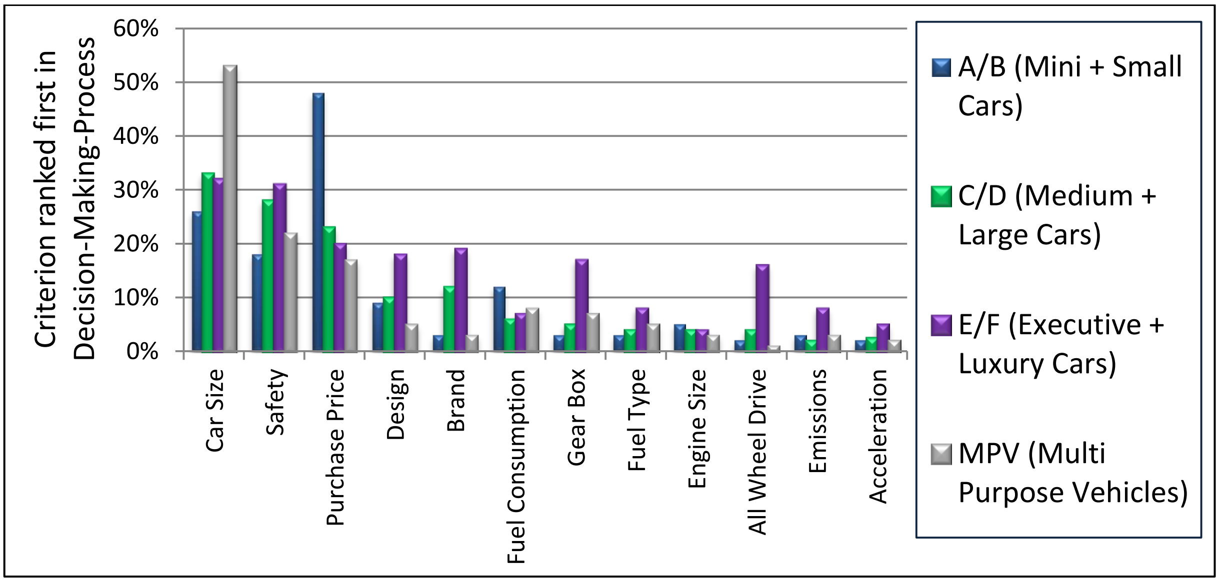

Figure 4-5: Decision-Criterions in Car Purchase[129]

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[128] Cf. Peters/de Haan (2006), pp. 32-41
[129] Cf. Peters/de Haan (2006), pp. 32-41, own illustration

4.2 Market Development

With growing population and increasing prosperity, overall car ownership levels will rise in the period to 2025. Due to the fact that the markets in North America, Japan/Korea and Europe are highly competitive and saturated the growth will mainly take place in China, India, Russia and Brazil. As shown in Figure 4-6 China and India are expected to have the highest compound annual growth rate (CAGR) till 2025 in terms of cars per 1000 inhabitants, which underlines the decision to focus on these regions.[130]

Compound Annual Growth Rate is the year over year growth rate of an investment over a definite period of time. The compound annual growth rate is calculated by taking the n^{th} root of the total percentage growth rate. N is hereby the number of years which are considered in the time period.[131]

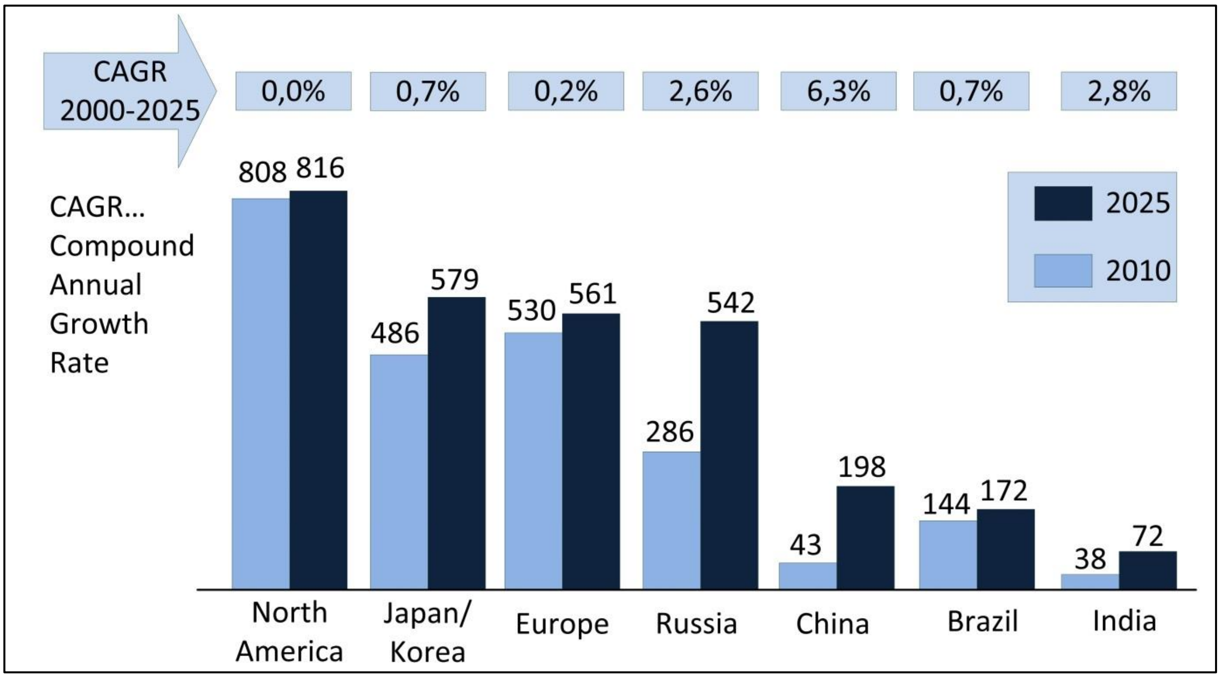


Figure 4-6: Cars per 1000 Inhabitants[132]

As already mentioned the purchasing power and the available market potential have a big influence on the expected market growth. The forecast includes the number of projected sales and production in the selected regions. The number of produced cars builds the basis for the further calculation of the tool steel demand. To create this

[130] Cf. Kalmbach et al. (2011), p. 23
[131] Cf. Tinz (2010), p. 97
[132] Kalmbach et al. (2011), p. 23, own illustration

chart data from a leading market analyst, LMC Automotive, was analysed. The solid dots show calculated values for the regarding year by the analysts, whereas the dotted lines are an interpolation to create a connected function. Figure 4-7 illustrates the automotive market forecast for passenger vehicles.[133]

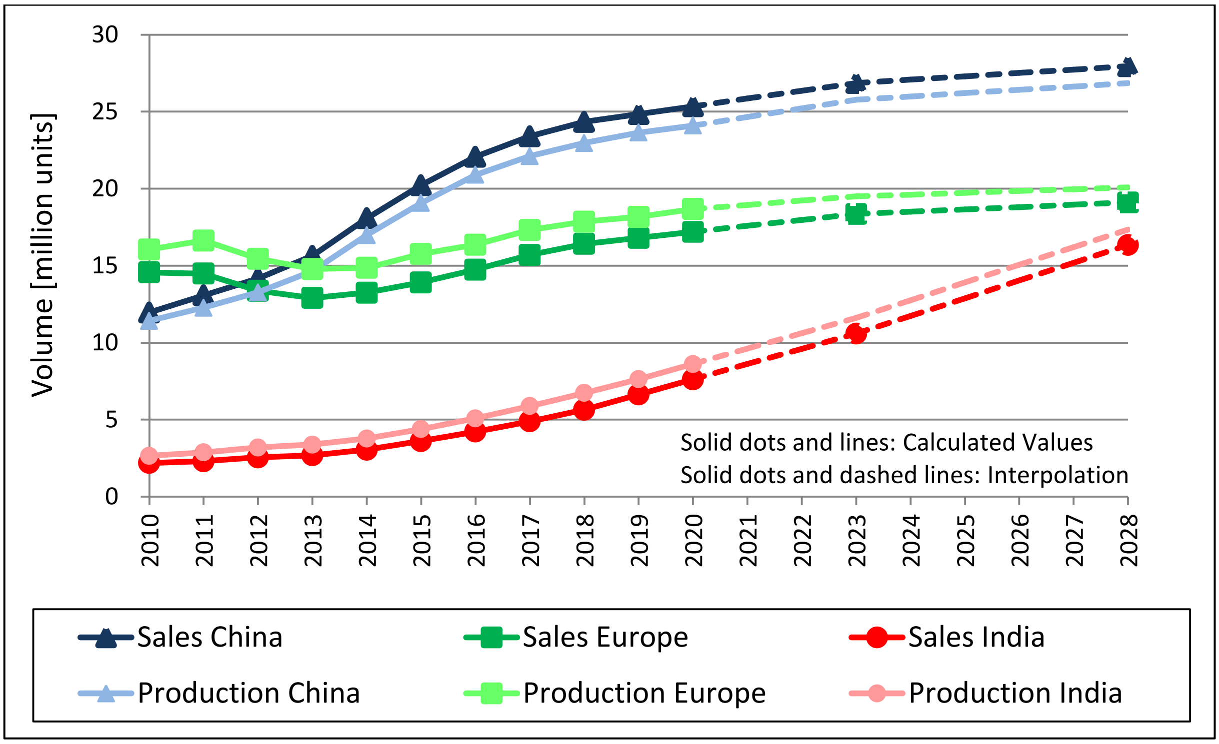


Figure 4-7: Passenger Vehicle Sales and Production for selected Markets[134]

Chinas passenger car market will continue the fast growing tendency and is expected to reach about 28 million units by 2028, which means almost double the amount of today. India will see a very steep curve reaching about 16 million cars in 2028, around six times as much as today. The European market is very advanced and mature with estimated 19 million cars in 2028. The difference between production and sales occurs due to imports and exports. The figures for production include all cars produced in the selected region, including manufacturing from foreign car manufacturers. Important to note is that the uncertainty of such forecasts increases the more one is looking into the future, but on the other hand it is not a problem if the numbers a varying in a range of a 2 or 3 million units as long as the overall trend continues.[135]

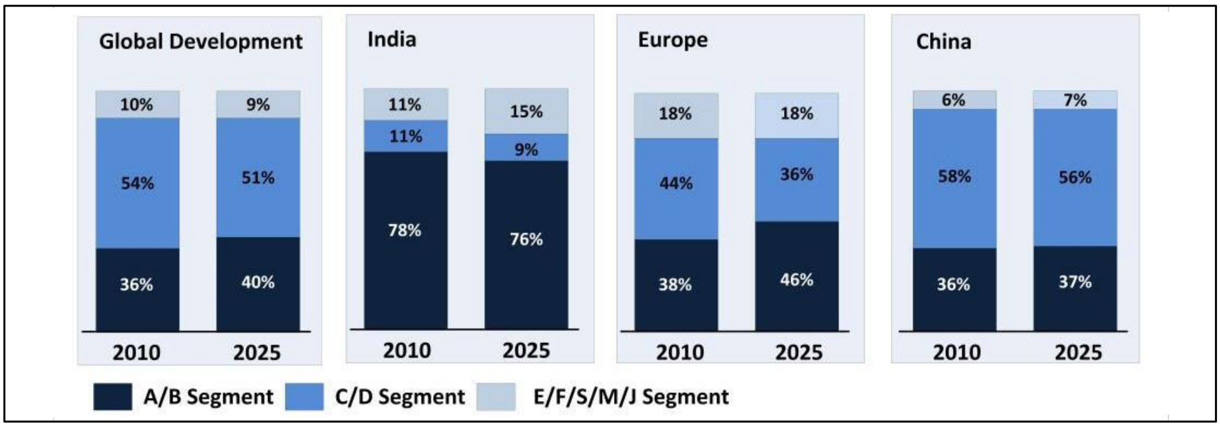
[133] Data from LMC Automotive, Uddeholm internal, accessed April 10th 2013
[134] Data from LMC Automotive, Uddeholm internal, accessed April 10th 2013, own illustration
[135] Data from LMC Automotive, Uddeholm internal, accessed April 10th 2013

The next step is to investigate these sales and production figures more into detail, concrete to divide them into the different car segments.

The car segments according to the European Commission are defined as follows:[136]

- A: Mini cars
- B: Small cars
- C: Medium cars
- D: Large cars
- E: Executive cars
- F: Luxury cars
- S: Sport cars
- M: Multi-Purpose Vehicle, Vans
- J: Sport Utility Vehicle

The development in Europe shows an increase of smaller cars (A-/B-segment) in terms of market share for the year 2025. The A-/B-/C-/D-segments (also named as volume segment afterwards) together are responsible for more than 80 percent of the total market. The situation in China is quite similar to Europe with a slightly smaller share of A-/B-segment cars, whereas here again over 90 percent are covered by the volume-segment. These two markets go accordingly with the global development. In India the distribution between the segments is different. The A-/B-segment covers around 70 percent of the market, which is almost twice as much as in Europe and China. Adding up the four main segments (A/B/C/D), India has a similar number with more than 80 percent of the total market. These facts allow the conclusion that the volume-segment is the main focus for further development of the study. Figure 4-8 illustrates the distribution of passenger vehicles by segment and region in comparison of 2010 and 2025.[137]



[136] Commission of the European Communities, accessed April 10th 2013
[137] Cf. Kalmbach et al. (2011), p. 52

Figure 4-8: Distribution of Passenger Vehicles by Segment and Region[138]

4.2.1 European Passenger Car Market

The European market covers the 27 member states of the European Union. A list of the countries can be found in Appendix F. This makes it possible to create a homogenous economic region where all relevant EU legislations are integrated.

The European passenger car market is in a quite difficult situation right now. Not all car makers used the crisis in 2008-2009 to prepare properly for coming years. The years 2010 and 2011 were a phase of stabilisation and the forecasts for the European market became more and more optimistic. For 2012, it turned out that the growing uncertainty due to the financial and economic crisis as well as the economic downturn in southern Europe has blurred the outlook for the coming years.[139]

Figure 4-9 illustrates the negative development in the European market over the last 12 months which shows eleven times a decrease in sales volume.

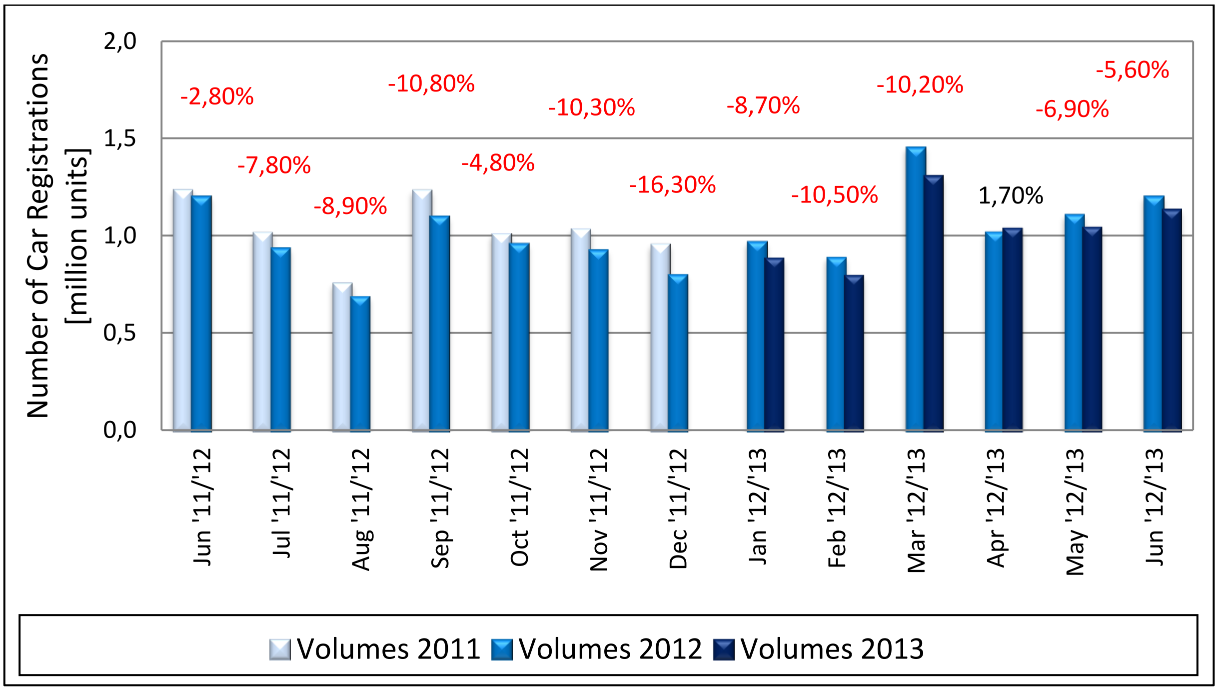


Figure 4-9: New Passenger Car Registrations in the EU - Last 12 Months[140]

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[138] Data from LMC Automotive, Uddeholm internal, accessed April 10th 2013 and Kalmbach et al. (2011), p. 52, own illustration

[139] Cf. Haas/Rapp (2012), p. 2-3

[140] ACEA (2013), Dataset, own illustration

In terms of market share European and North-American car manufacturers dominate the market. Volkswagen is leading, followed by PSA (Peugeot Société Anonyme), Renault and General Motors as shown in Figure 4-10.

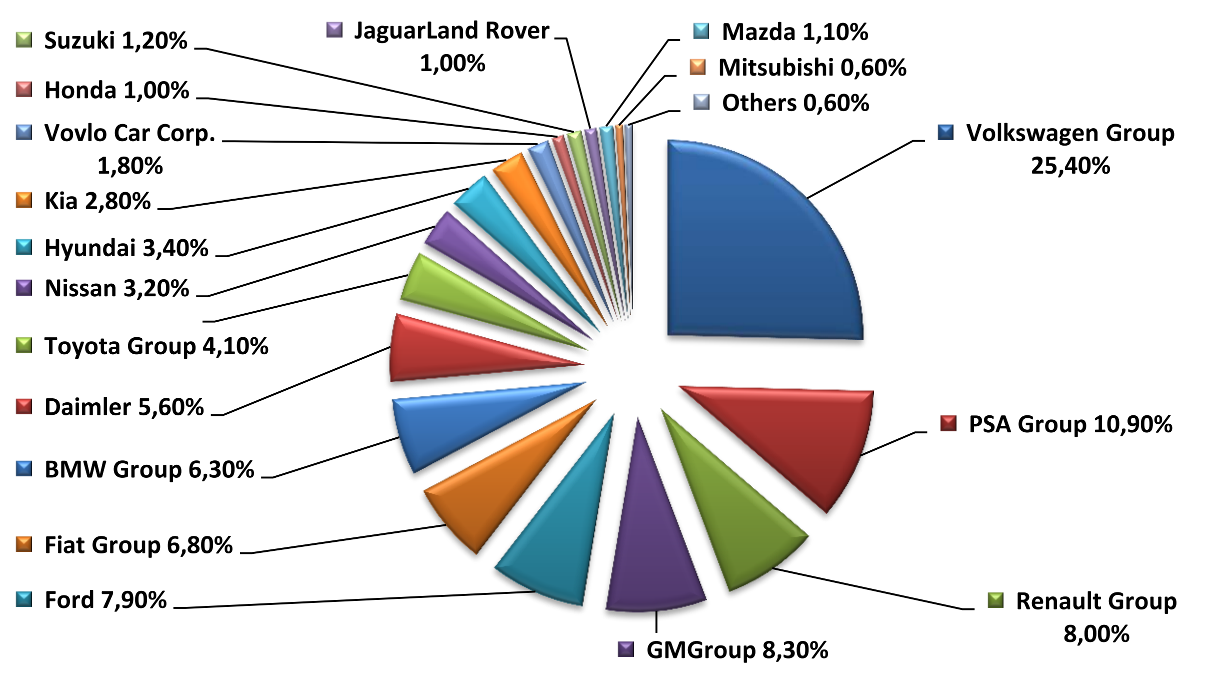

Figure 4-10: Market Share by Group in Europe[141]

4.2.2 Chinese Passenger Car Market

China's situation looks much brighter than in Europe. The country's economy, particular the gross domestic product, is expected to continue to grow over the next 10 years as already shown in Figure 4-1. The quality of roads has improved significantly in recent years and it is likely that this trend will continue in future. On the other hand the government is an uncertain factor in China which can enact a law affecting the automotive industry very quickly. It might be possible that car use in big cities is restricted to deal with the growing air pollution and congestion problems.[142]

Compared to Europe the Chinese market shows a positive development in new car registrations and is supposed to do so in future.[143]

Figure 4-11 shows a chart which seems to be mirrored to Europe concerning the percentage change to last year. Here once the development is slightly negative.

[141] ACEA (2013), p. 4, own illustration
[142] Cf. Wang/Liao/Hein (2012), pp. 2-3
[143] Cf. China Association of Automobile Manufacturers (2013), Dataset

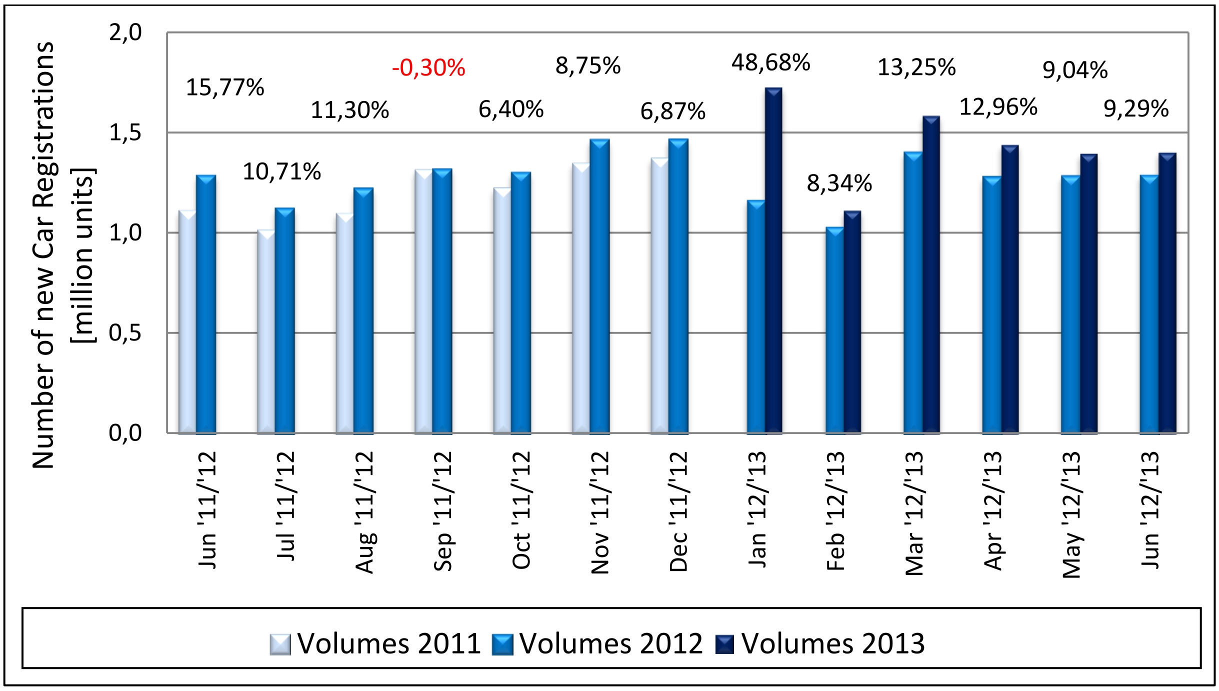

Figure 4-11: New Passenger Car Registrations in China- Last 12 Months[144]

In the Chinese light vehicle sector around 75 domestic brands and over 30 foreign brands compete. The market leaders are the foreign brands accounting for six of the top-ten brands as shown in Figure 4-12.[145]

As the foreign brands lead the market in terms of market share, they also do in terms of technology. New technology is mainly introduced by foreign manufacturers and within 2 or 3 years it is most likely copied by the Chinese car makers.[146]

[144] China Association of Automobile Manufacturers (2013), Dataset, own illustration
[145] Cf. Storey (2012), p. 1
[146] Discussion Mr Eason Fan, Business Development Manager (Automotive), ASSAB Tooling Technology (Shanghai) Co. Ltd, 16th of May 2013

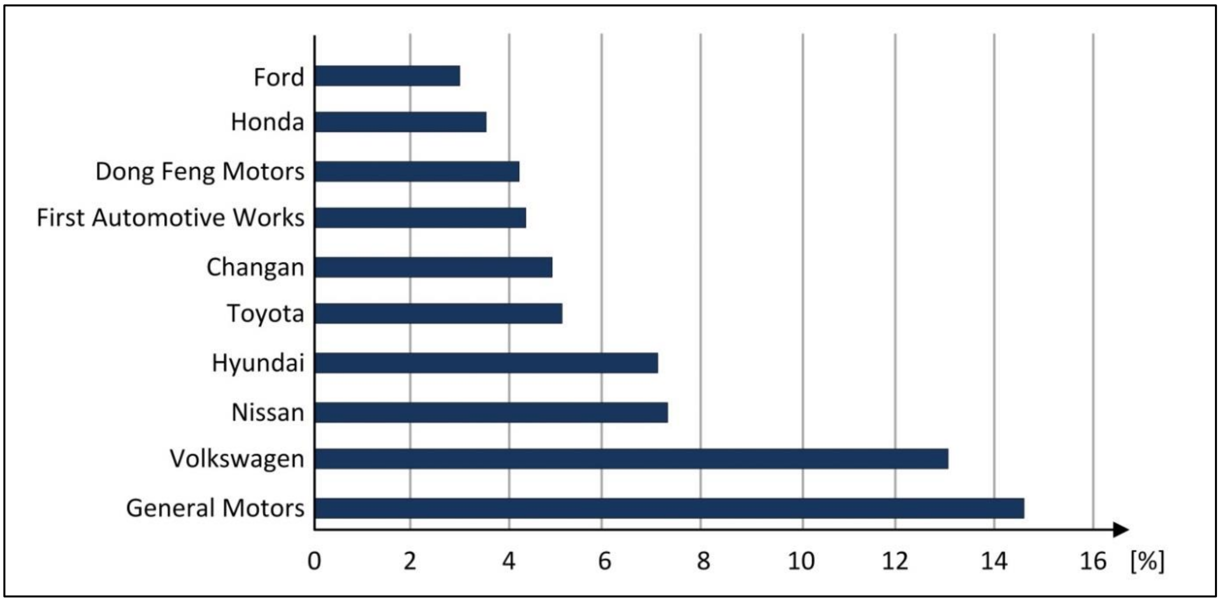

Figure 4-12: Top-10 Light Vehicle Market Share per Group[147]

General Motors and Volkswagen are the leading groups in the Chinese market followed by Nissan and Hyundai. A speciality of the market is that foreign companies have to form joint ventures with domestic companies.[148]

In 2004, the Chinese government released its policy on development of the automotive industry. The goal was to encourage manufacturers to improve their Research and Development and actively develop products with China's own intellectual property. Foreign car manufacturers are restricted to minority ownership in no more than two passenger vehicle assembly joint ventures.[149]

"Foreign investment in vehicle assembly projects continues to be capped at a maximum of 50 percent, which may come as a disappointment, but not a surprise, to some foreign companies. Given the Government regards automotive as a pillar industry it was expected that a degree of control over ownership would be retained."[150]

The conclusion of this governmental restriction for foreign car manufacturers is, that if they want to enter the Chinese market they have to do form joint venture with a domestic group. This leads obviously to a very important knowledge transfer for the Chinese manufacturers and is the main reason why they learn a lot from the foreign manufacturers.

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[147] Cf. Storey (2012), p. 9, own illustration
[148] Cf. Storey (2012), p. 9-10
[149] Cf. Hammer/Linton/Wise (2011), p. 5-35
[150] Brough et al. (2004), p. 1

4.2.3 Indian Passenger Car Market

The Indian automotive market is expected become an increasingly important player in future, but the question is how long it will take. The automotive sector in India is quite young, just over six decades old. The industry has grown within the past years and is now the seventh largest in the world. For many years the automotive industry was dominated by Maruti in the car sector, Mahindra and Mahindra in the J-segment and Tata and Ashok Leyland in the commercial vehicle sector. In recent years the industry structure has changed with Tata becoming a more significant force. Also the number of plants by foreign-owned car manufacturers is rising.[151]

In terms of market share the Maruti Suzuki Group is still leading in front of Mahindra and Hyundai as shown in Figure 4-13.

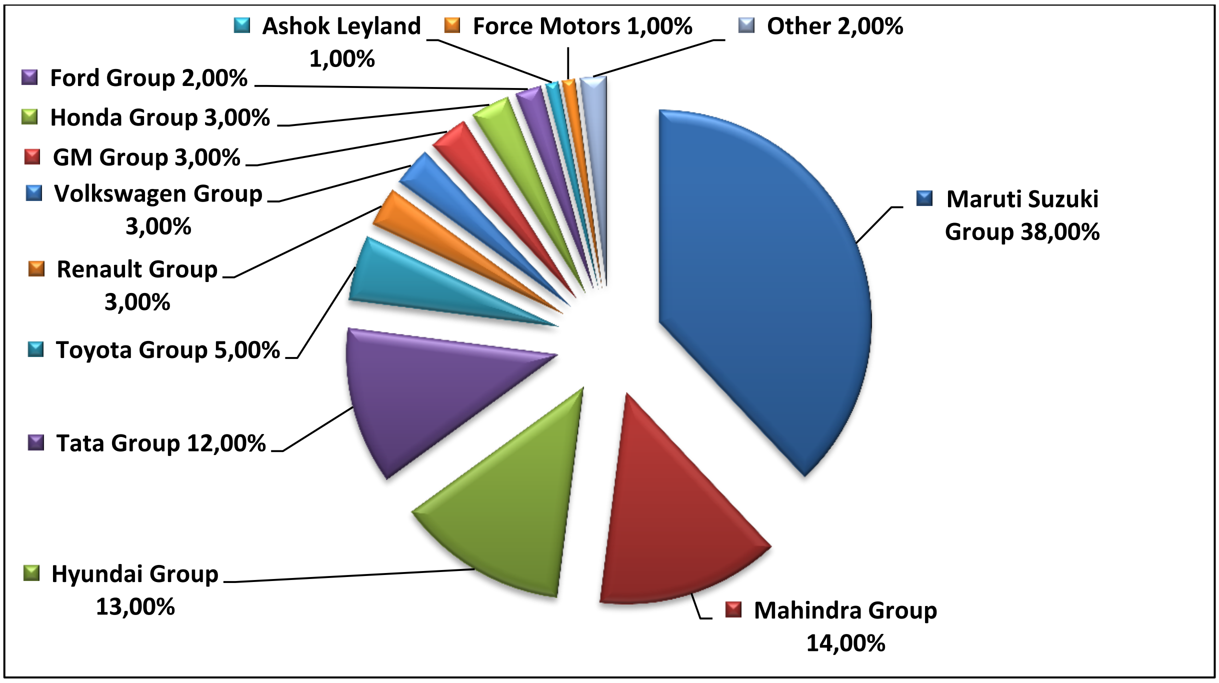

Figure 4-13: Market Share by Group in India[152]

The Indian motor vehicle market differs to Europe and China in a way that it is dominated by two wheelers, because of the affordability issues. They have a share of more than 75 percent as illustrated in Figure 4-14. Together with the affordability growing congestion problems in urban areas make it reasonable why people prefer a motorbike instead of a car. Another topic is that the infrastructure, like paved roads

[151] Cf. Kahl et al. (2011), p. 7
[152] Cf. Asher/Tunhau (2013), p. 6, own illustration

and parking space, still has a long way to go to reach a level which can deal with higher traffic volume.

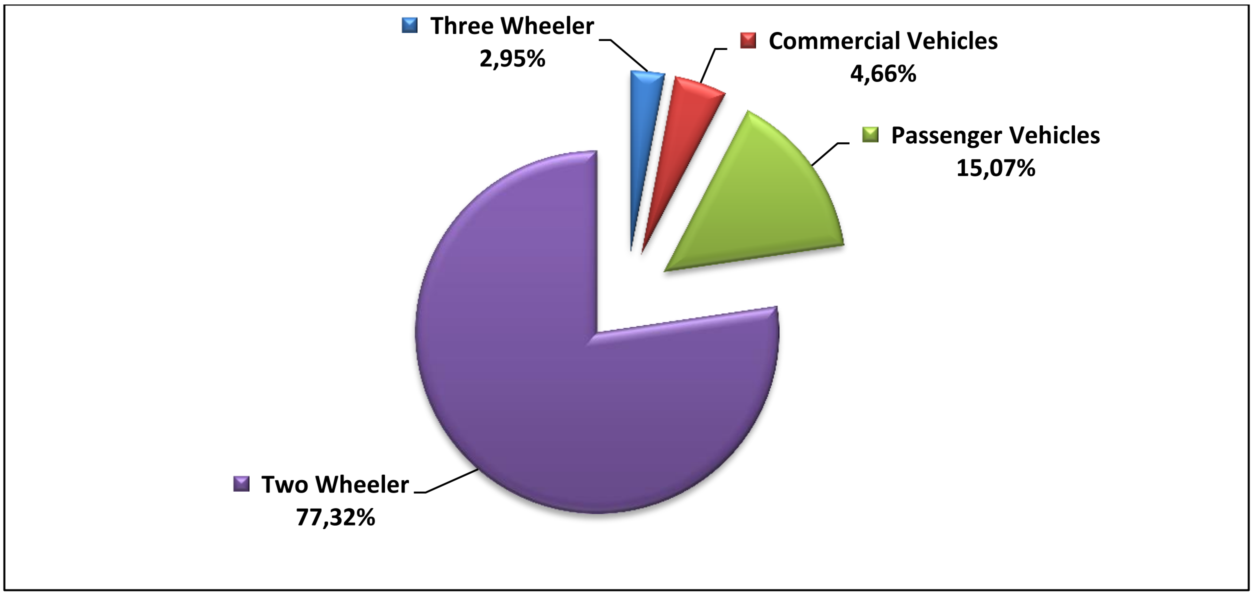

Figure 4-14: Motor Vehicle Market in India - Market Share by Type of Motor Vehicle[153]

4.3 Conclusion

The Indian and Chinese market bears a big potential for future, whereas the growth opportunities in the European market is quite low. It can be said that a dramatic shift to the Asian market will take place. For this reason production locations and sales will be affected by this trend. There will be a great demand of cars on the entry level (A-/B-segment) and the midsize segment (C-/D-segment). Another indicator confirming this trend is the vehicle ownership level in India and China. Compared with the gross domestic product per capita it is far behind the advanced economies as shown in Figure 4-2. To consider is that it is not expected that the Chinese and Indian ownership level will ever reach the same values as in the advanced economies due to the problems of congestion and pollution, what we already see today. Therefore these markets will reach saturation stage earlier.[154]

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[153] Society of Indian Automobile Manufacturers (2012), Dataset, own illustration
[154] Cf. Storey (2012), p. 6

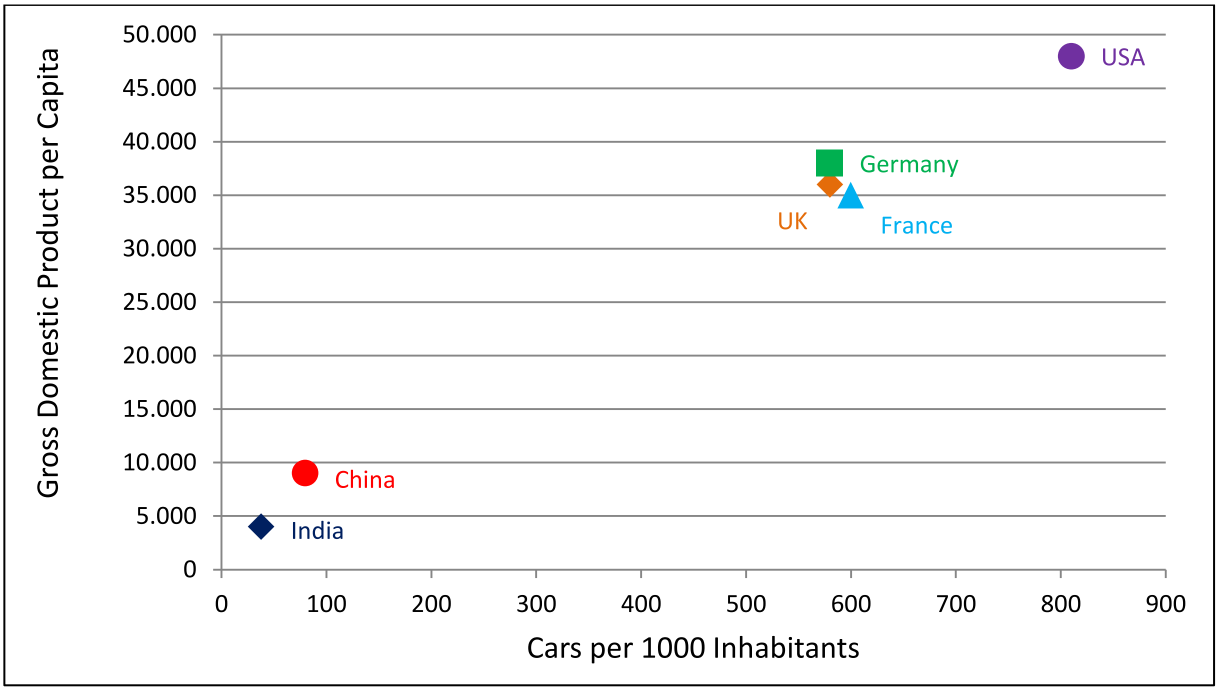

Figure 4-15: Vehicle Ownership Level compared to GDP 2012[155]

Summarized it can be said that the actual low car penetration in connection with the rising prosperity due to the economic growth in India and China leads to the positive forecast for the automotive industry in these markets, but both countries are still facing problems with the infrastructure and growing congestion problems, this will be one of the bottlenecks in future development.

[155] Cf. Storey (2012), p. 6

5 Emission Regulations – The Main Driver for Change

The development in powertrain technologies is one important factor which should be considered when analysing the future development in the automotive market. A new propulsion system can change the layout and design of the whole car and therefore it is very important to figure out which trends are coming up.[156] The main driver for developing new powertrain systems is to fulfil the fuel economy standards.[157] Figure 5-1 shows the emission targets announced from the governments.

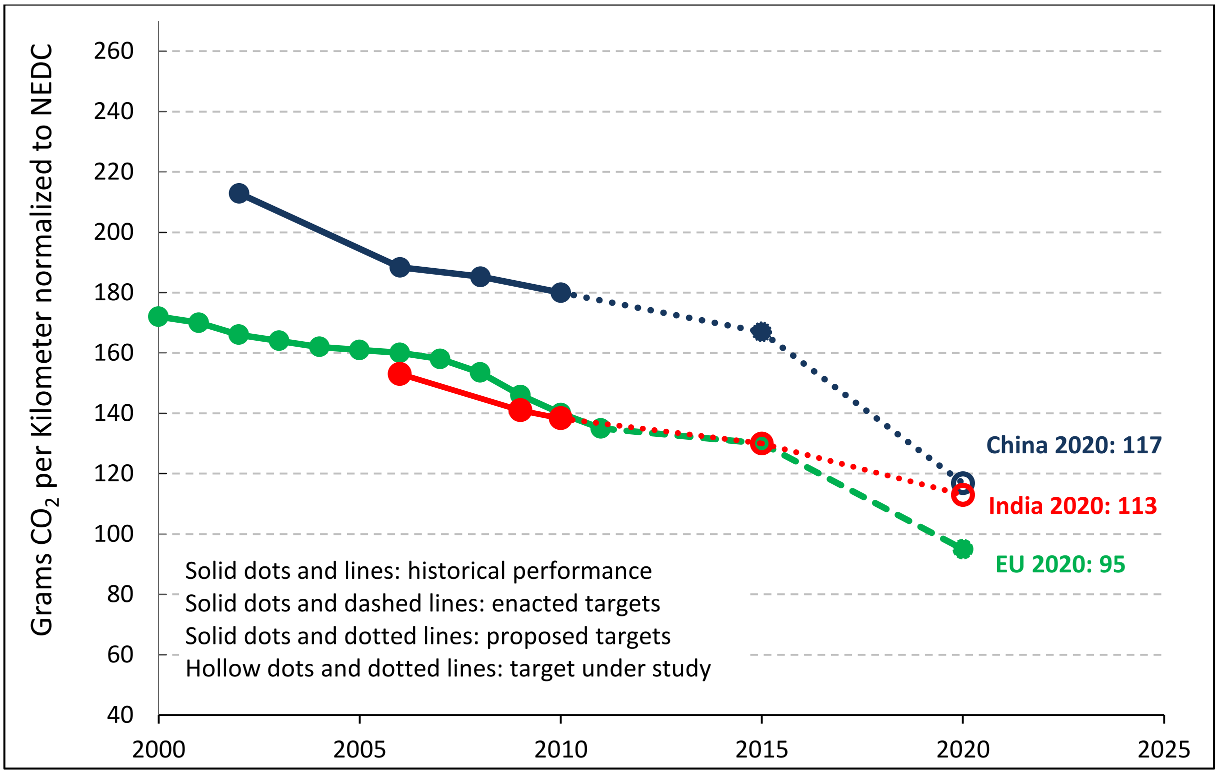

Figure 5-1: Global Fuel Economy Standards[158]

Figure 5-1 indicates the desired development, normalized to the New European Driving Cycle (NEDC, details in Appendix A), in the global fuel economy standards very well. All governments listed propose a decrease in emission which puts a high pressure on the car manufacturers to develop more efficient vehicles to meet the future requirements and avoid penalty payment. The European Union has the most aspirating goals with a proposed target of 95 grams carbon dioxide (CO_2) per

[156] Cf. Landesagentur für Elektromobilität und Brennstoffzellentechnologie Baden-Würtemberg (2012), p. 13
[157] Cf. German (2013), p. 4
[158] International Council on Clean Transportation (2013), Dataset

kilometre in 2020. China and India have their targets for 2020 still under study whereas 117 grams CO_2 per kilometre for China and 113 grams CO_2 per kilometre for India seem to be very ambitious. As the goals for the emerging markets are that aspiring, the question is how these regulations will be monitored. It is to expect that the targets of the European Union are reviewed much more accurate than in India and China.[159]

Discussion with Mr Eason Fan about the question, how strict is the monitoring of the emission standards in China.

In his opinion local Original Equipment Manufacturers (OEMs) are not yet so developed to meet high standard, and government consider automotive industry is one of the most important industries for China, they have to balance the technical status, environment and economy. Generally China is around 5 years later as Europe. The environmental control in China will be definitely stricter. At least the central government is paying more and more importance on environment protection. For example, now we are following China IV emission standard, and from 2018 all over China will follow China V, of course the cities like Peking, Shanghai will start much earlier. However, there's a barrier from local government where local OEMs are located, from whom local government earns money and local GDP, so there will be also fight between central and local government.[160]

5.1 **Penalty Payment**

The reason why the car manufacturers are so eager to meet these CO_2 restrictions is the penalty payment in the European Union. The European Commission passed a regulation (REGULATION (EC) No 443/2009) which defines the amount to pay if the emission targets are exceeded. Figure 5-2 shows graphically how the penalty payment increases over exceeded grams CO_2 per kilometre. The reason which makes this regulation so effective is that the penalty payment is multiplied with the number of sold cars. Details out of the regulation can be found in Appendix B.[161]

[159] International Council on Clean Transportation (2013), Dataset

[160] Discussion with Mr Eason Fan, Business Development Manager (Automotive), ASSAB Tooling Technology (Shanghai) Co., Ltd

[161] The European Parliament and the Council of the European Union (2009), REGULATION (EC) No 443/2009 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 23 April 2009 setting emission performance standards for new passenger cars as part of the Community's integrated approach to reduce CO2 emissions from light-duty vehicles

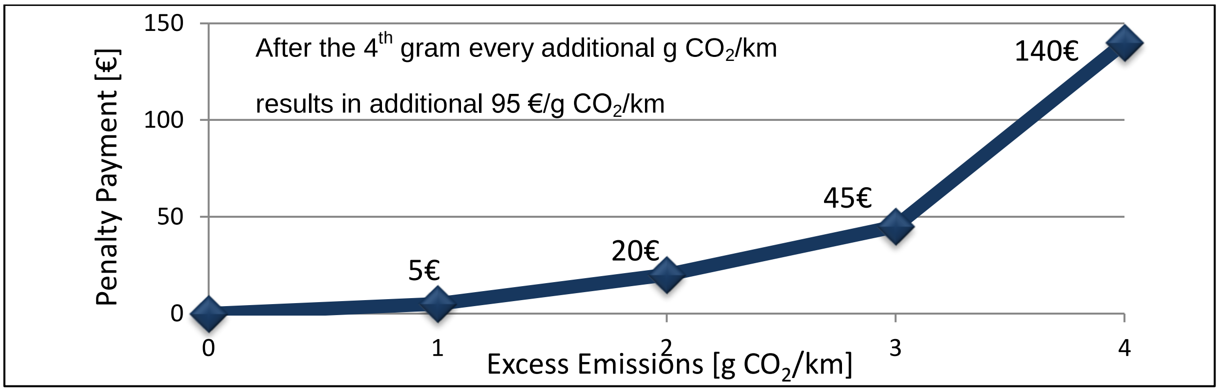

Figure 5-2: Penalty Payment Function by Excess of Emission Target[162]

The introduction of CO_2 emission standards already led to a better fuel efficiency of passenger vehicles sold in the European Union. Figure 5-3 shows that car manufacturers already reached a significant improvement in CO_2 reduction. PSA, Toyota and Fiat already fulfil the limits for 2015 whereas others still need some enhancement. In average another 5 percent are necessary. However to reach the targets for 2020 all manufacturers have to increase the efficiency of their cars.[163]

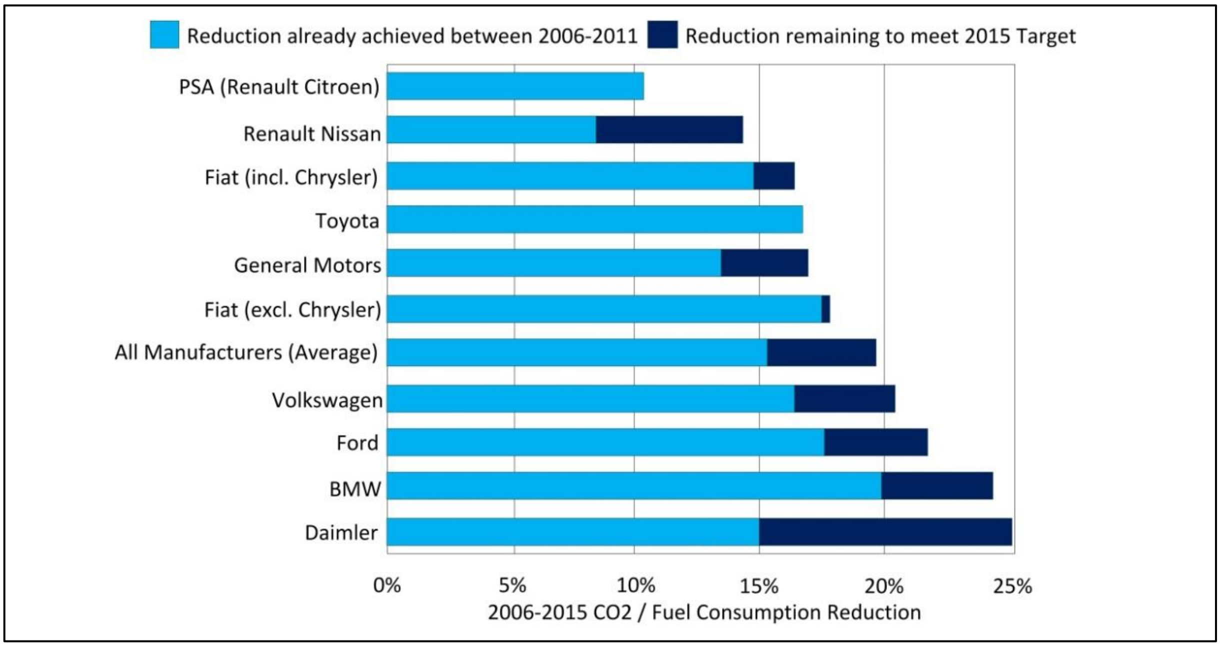

Figure 5-3: Percentage of CO_2 Reduction required to meet 2015 Target[164]

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[162] Cf. The European Parliament and the Council of the European Union (2009), REGULATION (EC) No 443/2009 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 23 April 2009 setting mission performance standards for new passenger cars as part of the Community's integrated approach to reduce CO2 emissions from light-duty vehicles

[163] Cf. International Council on Clean Transportation (2012), p. 2

[164] International Council on Clean Transportation (2012), own illustration

5.2 Conclusion

There are a few ways to meet this challenge and avoid penalty payment as shown in Figure 5-4. The powertrain accounts for 42 percent of the total fuel consumption and also the vehicle weight is responsible for almost another fourth (including secondary effects). The rest is related to aerodynamics, rolling resistance and electric systems. As major changes in the powertrain sector can have a massive impact on the car body structure and further on the used material in the car body, the development in this area is of high interest. The vehicle weight is the second area which influences the used material in the car body.[165]

On the basis of these findings the further investigation is focussed on the powertrain development and the material development in car body design.

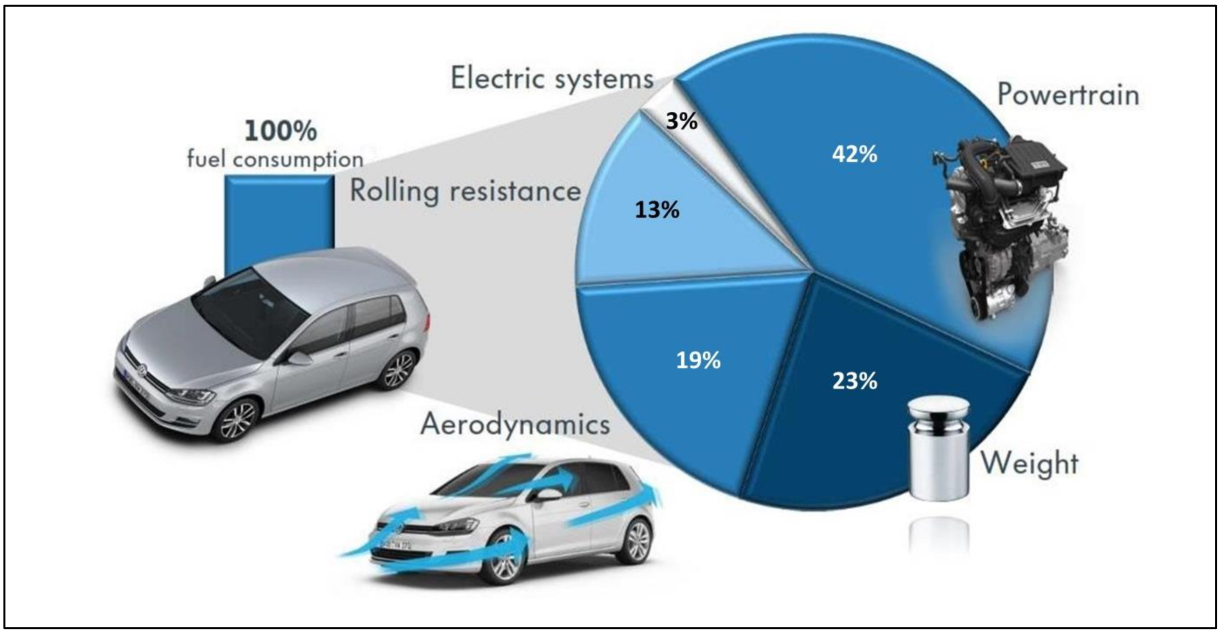

Figure 5-4: Main Fuel Consumers in a Car[166]

[165] Cf. Leohold (2012), pp. 5-8
[166] Hillman (2012), p. 9

6 Development in Powertrain Technology

The development of new powertrain technologies till 2025 can have a substantial impact on the car body design. Whereas the conventional combustion engine and the different variants of hybrid electric vehicles require no big changes in the body structure, this can be the case for completely new developed electric vehicles. The development in propulsion systems will go towards to more hybrid electric vehicles. Hybrid vehicle means a combination of two different energy converters and two different energy storage systems. Pure electric vehicles will play a minor role till 2025 because of insufficient infrastructure for recharging the battery, limited range, high vehicle weight and high battery costs. From a present day perspective pure electric vehicle can change the powertrain scenario just with a technological breakthrough in battery technology; otherwise it is not likely that they gain a big market share within the next 10 years.[167]

Figure 6-1 shows the expected change in the powertrain scenario till 2025 for Europe, India and China whereby the bubble size indicates the market size. In Europe the different types of hybrids will gain a maximum market share of around 36 percent, the internal combustion engine (ICE) will still account for more than 50 percent and the pure electric vehicle will reach around 10 percent. India will be dominated by the combustion engine with a maximum share of hybrids of around 15 percent. China has a similar distribution than Europe with 67 percent combustion engine, around 24 percent of hybrids and a share of 9 percent for pure electric vehicles.[168]

[167] Discussion Mr Nader Asnafi, Vice President – Research and Development, Uddeholms AB, 26th of June 2013, Hagfors

[168] Cf. Kalmbach et al. (2011), p. 56 and Klink et al. (2012), p. 18, own illustration

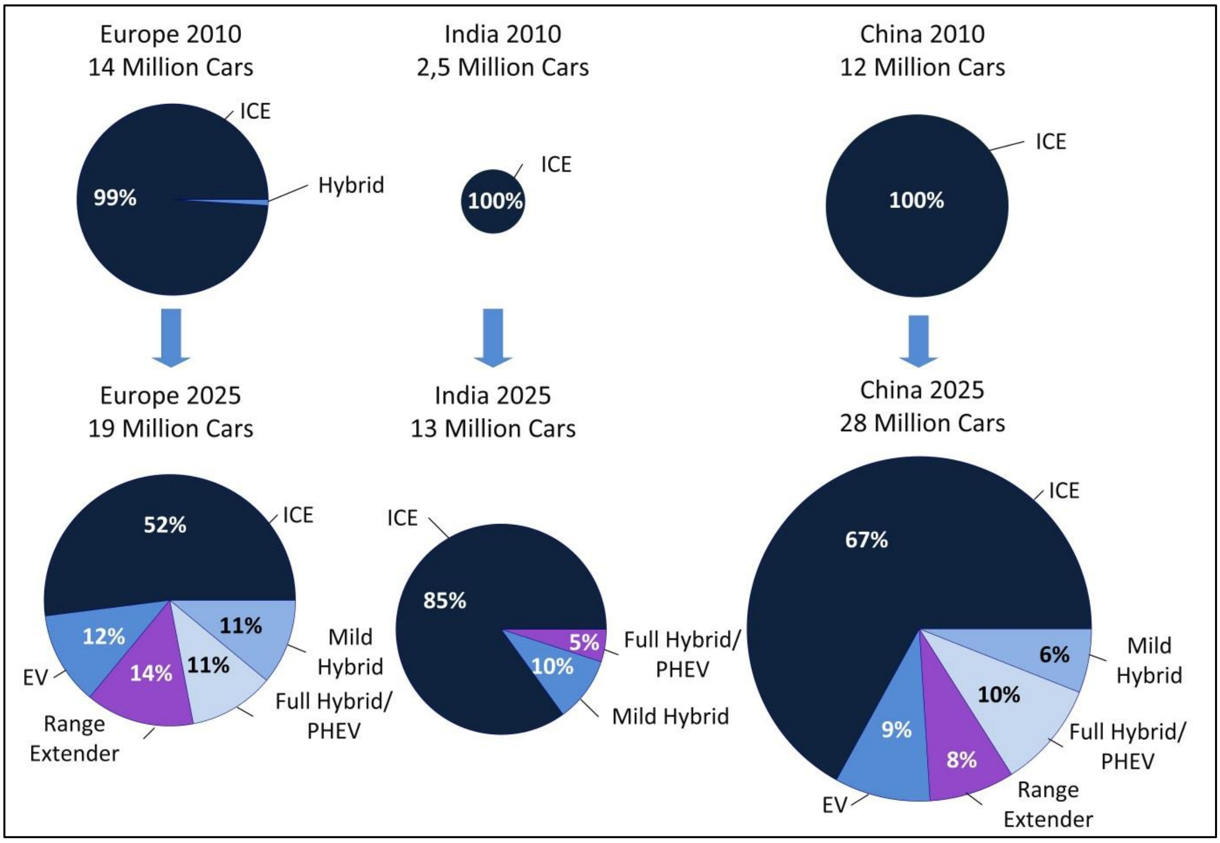

Figure 6-1: Powertrain Scenario Europe, India and China[169]

Figure 6-1 just provides overall information of the powertrain scenario. The next step of the investigation is to break up the powertrain development more into detail. In other words to take the number of sold cars together with the powertrain scenario and the distribution of car segments to calculate the number of produced cars per segment and powertrain for the regarded regions. The focus is again put on the volume segment.

6.1 Different Types of Alternative Powertrains

For the investigation there are different types of alternative powertrain considered. These are the Mild Hybrid, the Full-Hybrid, the Plug-In-Hybrid Electric Vehicle (PHEV), the Range Extender Electric Vehicle and the Electric Vehicle (EV).[170] This selection is just an overview of the different concepts to understand the basic idea behind the technology.

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[169] Cf. Kalmbach et al. (2011), p. 56 and Klink et al. (2012), p. 18, own illustration
[170] Cf. Reif (2010), p. 14

- Mild-Hybrid:
  The Mild-Hybrid as used nowadays in cars combines a combustion engine and an electric engine which are placed on the same shaft. The electric engine provides additional torque which supports the combustion to increase the efficiency. It is not possible to uncouple the electric engine from the combustion engine and therefore pure electric drive is in most cases not possible with Mild-Hybrids.[171]

- Full-Hybrid:
  The main difference between a Full-Hybrid and a Mild-Hybrid is that in this case the electric engine and the combustion engine are uncoupled. Together with a bigger battery system the Full-Hybrid vehicle is able to drive in pure electric mode.[172]

- Plug-In-Hybrid Electric Vehicle:
  Plug-In Hybrids are en evolution from the Full-Hybrids. Whereas for Mild-Hybrids and Full-Hybrids the battery pack is charged from on-board systems like regenerative breaking the Plug-In Hybrid Electric Vehicle gives the driver the option to charge the battery via cable. Other technical specifications are quite similar to the Full-Hybrid.[173]

- Range Extender Electric Vehicle:
  Range Extender Electric Vehicles are only powered by an electric engine. The battery pack provides the electricity whereas the combustion engine in this case is just responsible for recharging the battery. So the combustion engine has now connection to the drive shaft anymore.[174]

- Electric Vehicle:
  The electric vehicle is exclusively driven by an electric engine and the battery is the only power source. The recharging of the battery is done by on board systems during driving but mainly via plug in to a power outlet.[175]

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[171] Cf. Reif (2010), p. 14
[172] Cf. Reif (2010), p. 15
[173] Cf. Tonachel/Hwang (2007), p. 2
[174] Cf. Lu et al. (2010), pp. 1-2
[175] Cf. Parliamentary Office of Science & Technology (2010), pp. 1-2

6.2 Europe

The European market is on a very advanced technology level and therefore the highest amount of new powertrains in percentage is expected. Due to the stricter CO_2 regulations the trend is going to smaller vehicles and therefore the share of the A/B-segment will increase as shown in Figure 6-2. The portion of ICE powered vehicles will decrease also in absolute numbers because of the relatively small growth from around 16 million to around 20 million produced cars in 2025 and the use of more alternative propulsion systems.[176]

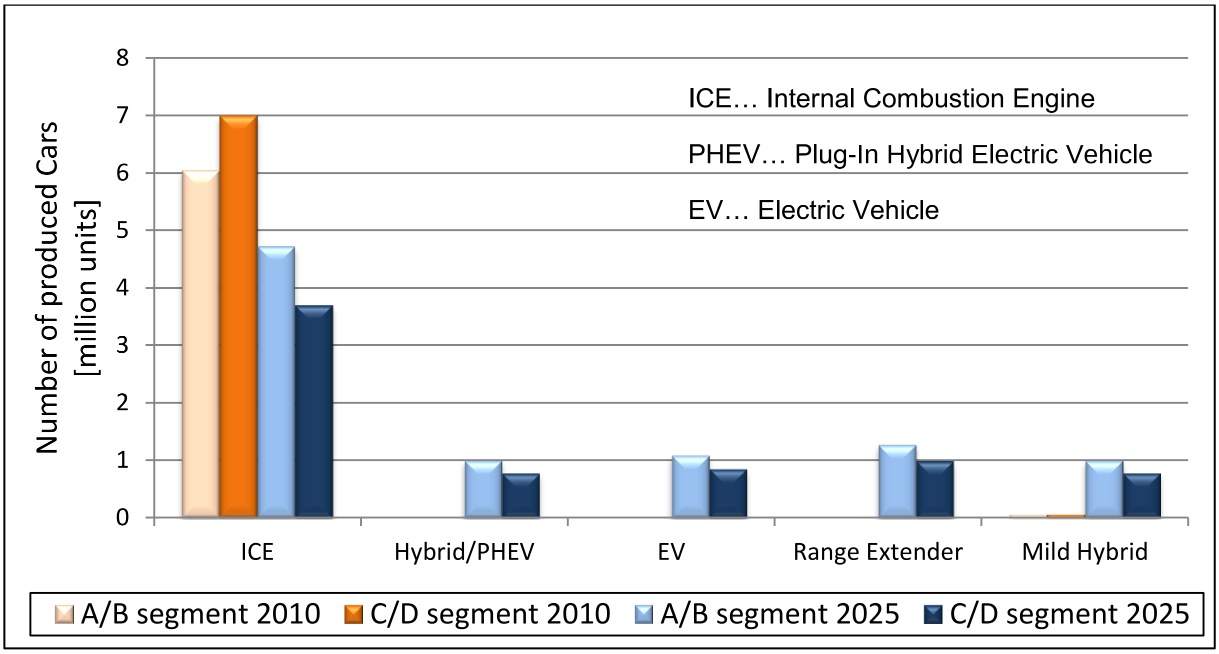

Figure 6-2: Produced Cars per Segment and Powertrain in Europe 2010-2025[177]

6.3 China

China varies in terms of segments, as the C/D segment is the most popular one. The big difference is the market size in 2025 with around 26 million vehicles compared to 11 million in 2010. Similar to Europe, in China the internal combustion engine still remains as the number one propulsion system for passenger vehicles. As China is struggling with massive air quality problems in megacities like Shanghai and Beijing the electric vehicle can be the winning concept for individual transport in the urban

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[176] Cf. Kalmbach R et al. (2011), p. 56, Klink G et al. (2012), p. 18 and Data from LMC Automotive (2013), Uddeholm internal

[177] Cf. Kalmbach R et al. (2011), p. 56, Klink G et al. (2012), p. 18 and Data from LMC Automotive (2013), Uddeholm internal

areas after 2025. Subsidies from the government can help the pure electric vehicle to gain more market share, but from where we stand now the pure electric vehicle has still a long way to go. Figure 6-3 shows the distribution of produced cars per segment and powertrain in China for 2010 and 2025.[178]

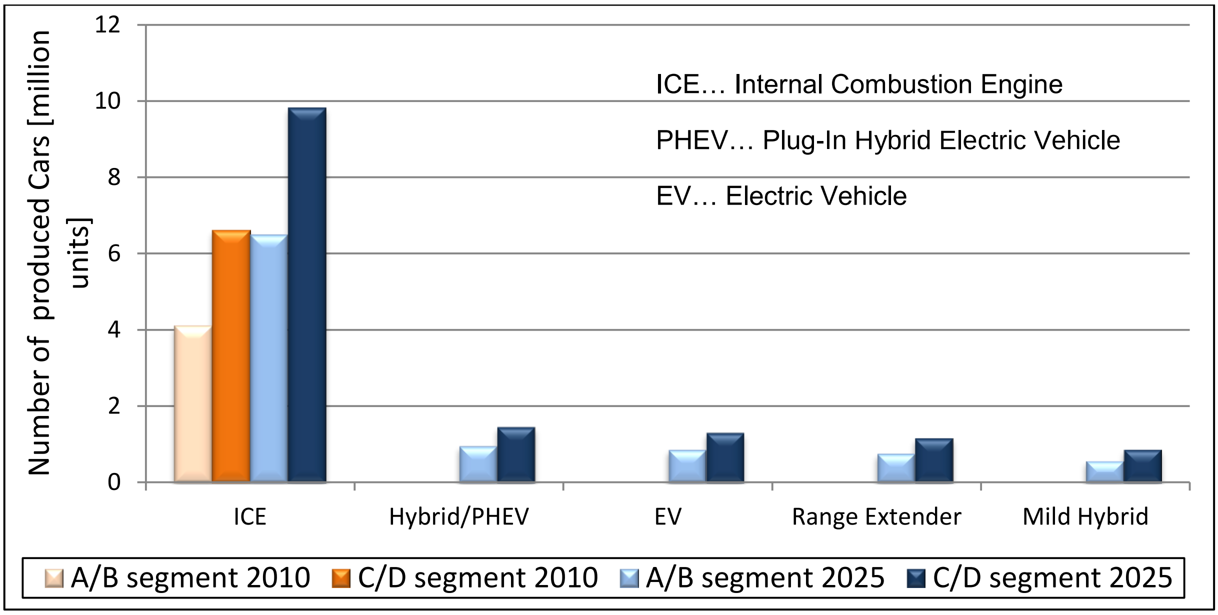

Figure 6-3: Produced Cars per Segment and Powertrain in China 2010-2025[179]

6.4 **India**

The Indian market is dominated by A/B segment vehicles powered by combustion engines; this is still likely to be stable till 2025 as Figure 6-4 illustrates. The most influencing factor is the enormous market growth from around 2,5 million to 14 million produced cars in 2025. Due to affordability issues the combustion engine is the propulsion system for the future and therefore the absolute numbers of alternative propulsion systems is negligible small.[180]

[178] Cf. Kalmbach R et al. (2011), p. 56, Klink G et al. (2012), p. 18 and Data from LMC Automotive (2013), Uddeholm internal
[179] Cf. Kalmbach R et al. (2011), p. 56, Klink G et al. (2012), p. 18 and Data from LMC Automotive (2013), Uddeholm internal
[180] Cf. Kalmbach R et al. (2011), p. 56, Klink G et al. (2012), p. 18 and Data from LMC Automotive (2013), Uddeholm internal

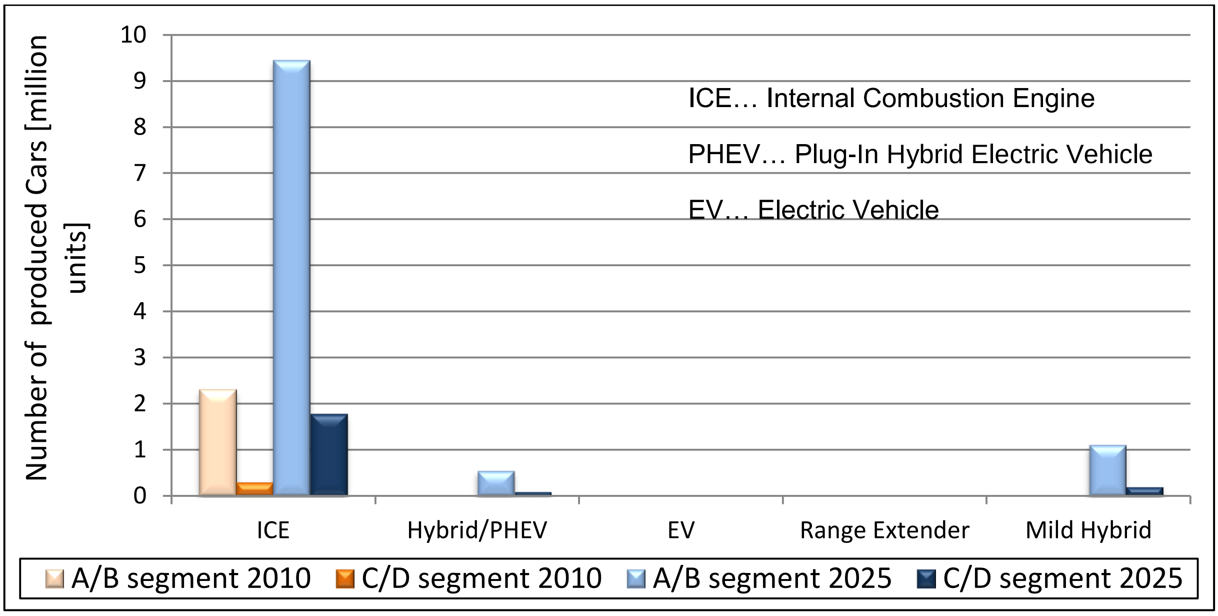

Figure 6-4: Produced Cars per Segment and Powertrain in India 2010-2025[181]

6.5 Trend in Propulsion Systems

To figure out a trend in the powertrain sector over the next years, the number of produced cars and the powertrain scenarios for 2010, 2015, 2020 and 2025 were combined. For long term perspective till 2025 only India has a positive trend concerning the combustion engine. China is expected to have a positive trend till 2020, because of the strong market growth the absolute number of cars with combustion engine still increases, whereas the trend form 2020 onwards is going down slightly. For Europe a negative trend in cars equipped with combustion engines can be anticipated due to two reasons. First the weak market development predicted and second Europe is the most advanced market in terms of technology, therefore the pure combustion engine is losing shares to alternative solutions. The negative development is due to the fact that hybrids gain more market share shown in Figure 6-6. Due to the fact that hybrids also use a combustion engine this engine type will still play an important role in future. Figure 6-5 indicates the trend for cars with conventional combustion engines.[182]

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[181] Cf. Kalmbach R et al. (2011), p. 56, Klink G et al. (2012), p. 18 and Data from LMC Automotive (2013), Uddeholm internal

[182] Cf. Kalmbach R et al. (2011), p. 56, Klink G et al. (2012), p. 18, Data from LMC Automotive (2013), Uddeholm internal and Roland (2010), p. 4

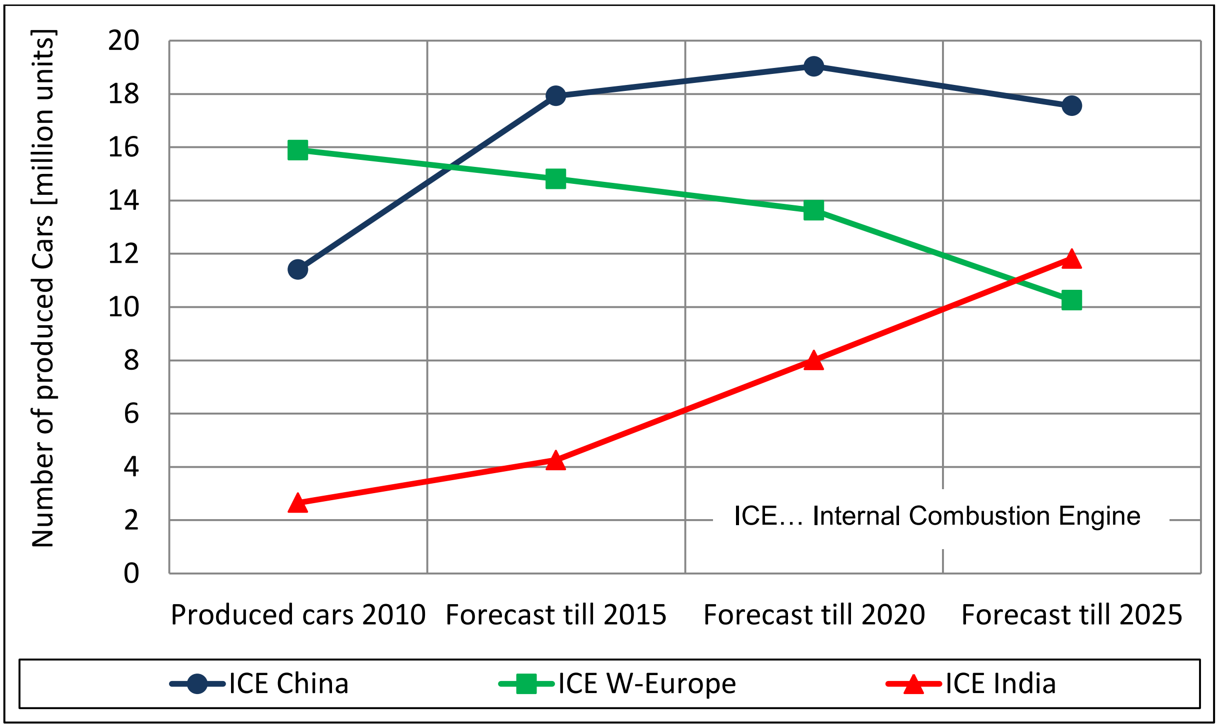

Figure 6-5: Development of ICE for Europe, China and India 2010-2025[183]

As the trend for conventional combustion engines is going downwards, the shares of alternative solutions are rising till 2025. In Figure 6-6 the development shows a positive trend for hybrids and electric vehicles. Hybrids in this chart combine all variants like plug-in hybrid electric vehicles, full hybrids, mild hybrids and range extender vehicles. Europe and China show a quite similar trend with a growing hybrid and electric vehicle segment. India is expected to have a slow development in alternative propulsion systems with almost no electric vehicles in future and a maximum of 2 million hybrid cars in 2025.[184]

[183] Cf. Kalmbach R et al. (2011), p. 56, Klink G et al. (2012), p. 18, Data from LMC Automotive (2013), Uddeholm internal and Roland Berger Strategy Consultants (2010), p. 4

[184] Cf. Kalmbach R et al. (2011), p. 56, Klink G et al. (2012), p. 18, Data from LMC Automotive (2013), Uddeholm internal and Roland Berger Strategy Consultants (2010), p. 4

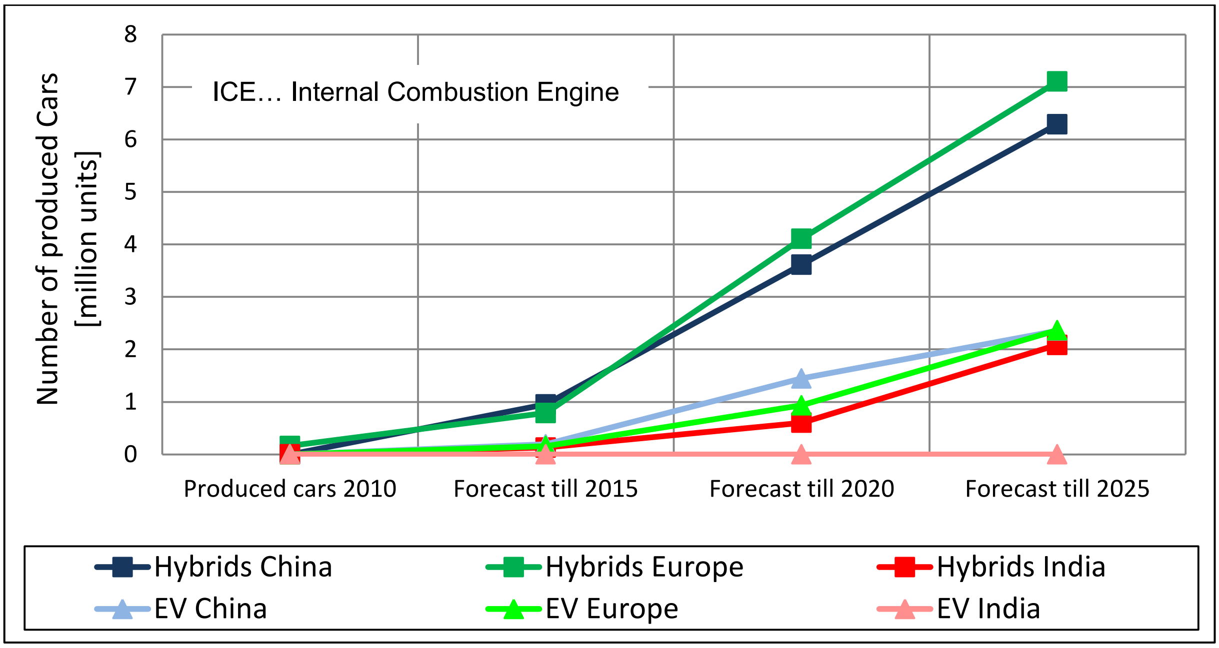

Figure 6-6: Development of Alternative Powertrains in Europe, China and India 2010-2025[185]

6.6 Conclusion

Due to the changing emission standards it is necessary for the car manufacturers to change their powertrain-portfolio. Overall the trend is moving to smaller and more efficient cars.[186]

Talking about alternative concepts, hybrid electric vehicles are expected to be the most promising choice, whereas also in this case just a few concepts are already on the market and in serial production.[187]

Electric vehicles are considered to stay a niche product as they still face a lot of problems from technological (limited range) and infrastructural side (recharging). Car manufacturers show a lot of concept cars with electric drive at several motor shows, but they are still in the development phase. It seems in most cases, that these projects are more used for marketing issues pushing the brand towards a more environmentally friendly image. It is still a long way to go before electric vehicles become a serious alternative in the volume segment.[188]

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[185] Cf. Kalmbach R et al. (2011), p. 56, Klink G et al. (2012), p. 18, Data from LMC Automotive (2013), Uddeholm internal and Roland Berger Strategy Consultants (2010), p. 4
[186] ibidem
[187] ibidem
[188] Discussion Mr Nader Asnafi, Vice President – Research and Development, Uddeholms AB, 19th of June 2013, Hagfors

Summarized the combustion engine will be the number one propulsion system for the next ten years as there is still space for improvement in efficiency and other technologies struggle with a lot of technological problems. Especially in the emerging markets where the affordability issue is of main concern there is no way to meet the market requirements without the combustion engine. So it is at this point not expected that there are big changes in the car body structure due to the influence of new powertrain systems.[189]

[189] Discussion Mr Nader Asnafi, Vice President – Research and Development, Uddeholms AB, 19th of June 2013, Hagfors

7 Car Body

The development in the area of the car body is of main interest for the further investigation of the tool steel demand. Firstly the trend is to build lighter bodies to increase fuel efficiency, as the whole vehicle mass accounts for around 25 percent of the fuel consumption, and maintain or even improve the existing level of safety. Lightweight design itself is not limited to the body structure, but tries to decrease the weight of all components in a car, like the closures, electrical components, engine parts and many more.[190]

The focus of this chapter is put on the body in white to investigate the development and changes in used material of structural parts. These parts require high quality tool steel and therefore the trend in this sector is of high interest for Uddeholms AB.

7.1 Strategies in Car Body Engineering

At the end of the 20st century car manufacturers were faced with a very dynamic market and had to change their manufacturing system. Mass-production was no longer applicable for meeting the customer requirements and therefore at the beginning of the 21st century a global production for a global market was required. That led in the end to the introduction of the mass-customization production system. Mass-customization means to offer customer-order specific products by still using the advantages of mass production. To benefit from these advantages in mass-production it is necessary to shift the point of customization to the end of the value chain as far as possible.[191]

When the end customer wants to order a new vehicle, a huge variety of options for the vehicle are offered. All kinds of different colours, an enormous selection of additional equipment, several different engine and powertrain options make today's cars to one of the most sophisticated products in the world.[192] The question is how car manufacturers are able to deal with these complex products, Audi (in Austria Audi is offering 42 different passenger car models[193]) should hereby serve as an example.

[190] Cf. Leohold (2012), pp. 4-8
[191] Cf. Ramsauer (2009), pp. 105-106
[192] Cf. Elend/Mlekusch (2013), p. 6
[193] Audi (2013), www.audi.at/modelle, accessed 23th July 2013

The solution is to separate into the world of product and world of production by making use of the philosophy of the modular system as shown in Figure 7-1.[194]

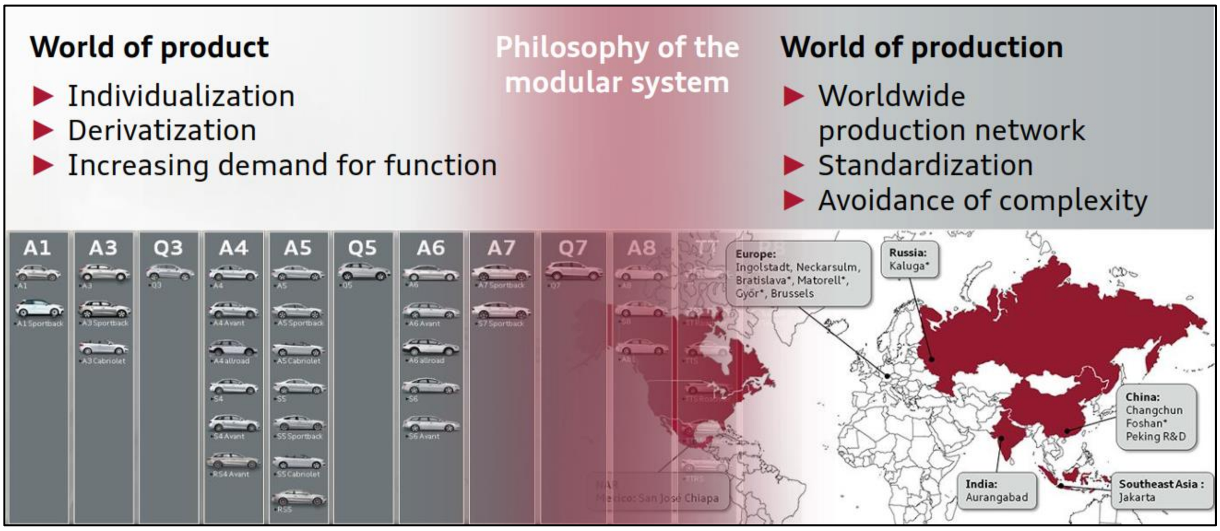

Figure 7-1: Philosophy of the Modular System at Audi AG[195]

Modular product architecture is a key issue when talking about mass customization. Products are divided into several modules with defined interfaces, these modules together then result in another bigger module or in a product.[196]

A result of this development is the use of the platform strategy that is applied by almost every car manufacturer all over the world today.[197]

“A product platform is a set of subsystems and interfaces that form a common structure from which a stream of derivate products can be efficiently developed and produced.”[198]

The very basic understanding which production strategy is applied in today’s car manufacturing makes it possible to draw conclusions from how a car is produced in Europe and how the production of the same car looks like in other regions.[199]

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194 Cf. Elend/Mlekusch (2013), p. 6
195 Elend/Mlekusch (2013), p. 6
196 Cf. Ramsauer (2009), p. 53
197 Discussion Mr Nader Asnafi, Vice President – Research and Development, Uddeholms AB, 26th of June 2013, Hagfors
198 Meyer/Lehnerd (1997), p. 39
199 Discussion Mr Nader Asnafi, Vice President – Research and Development, Uddeholms AB, 26th of June 2013, Hagfors

7.2 Analysing the Body in White

The material selection for the body in white, together with the chosen manufacturing method, is a major criterion for the tool steel selection. It furthermore influences many other parameters of the manufacturing process together with the tool and die design.[200]

Especially for the volume segment it is important to know which development in car body materials will dominate in future. Therefore the approach was to gather data concerning actual models within the C-segment. In most cases it was available in the form of tables or charts which show the material distribution. Together with forecast of and expectations of recent studies it was possible to figure out a trend for the body in white material mix. Figure 7-2 shows how the material distribution for an actual mid-class body in white looks like, in this case the Audi A3 with start of production in Europe 2012.

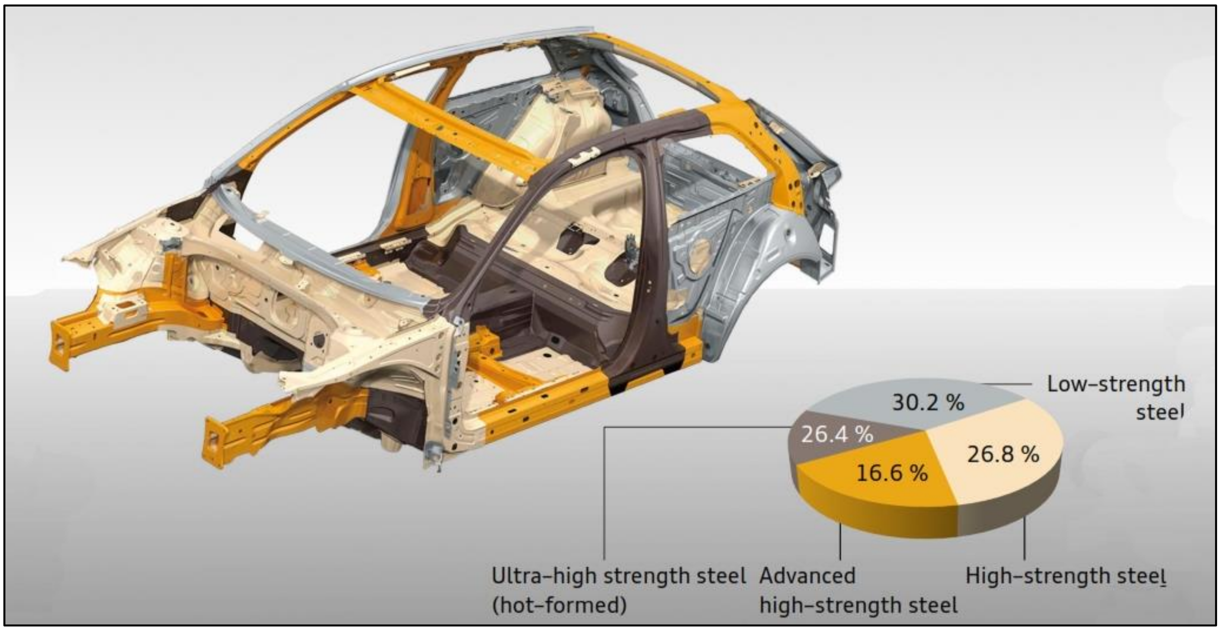

Figure 7-2: Car Body Material Mix Audi for the A3 (Model Year 2012)[201]

The example of the Audi A3 shows a material distribution of around 30 percent low strength steel, 27 percent high strength steel, 17 percent advanced high strength steel and 26 percent ultra-high strength steel.[202]

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[200] Discussion Mr Nader Asnafi, Vice President – Research and Development, Uddeholms AB, 19th of June 2013, Hagfors

[201] Bielz/Hein (2012), Presentation Audi AG, p. 24

[202] Cf. Bielz/Hein (2012), Presentation Audi AG, p. 24

In this case the manufacturer makes just use of different steel grades, but there can be a lot more materials like aluminium, magnesium and carbon fibre reinforced plastics.[203]

The question is how are these different materials defined? Therefore the first step before investigating the different car models was to set a definition, a material classification. This is an important step to make the data comparable and bring down everything to a common denominator.

7.3 Material Classification

The material mix is distributed into metallurgical and chemical classes. Steel is further divided into low strength steels, high strength steels, advanced high strength steels, ultra high strength steels and press hardened steels. Aluminium is divided into aluminium sheets, aluminium extrusion profiles and cast aluminium. Magnesium requires no further subdivision whereas the plastics are divided into fibre reinforced plastic, duroplastics and thermoplastics.[204]

As the different steel grades are of main interest for the thesis a more accurate definition is needed. Figure 7-3 provides an overview how the different steel grades are distributed over the yield- and tensile-strength. Low strength steels have the lowest strength followed by high strength steel and advanced high strength steel. Ultra high strength steel and press hardened steel build the top of the strength level of actual steel grades used in automotive industry.[205]

[203] Cf. Automotive Circle (2012a), p. 3
[204] ibidem
[205] ibidem

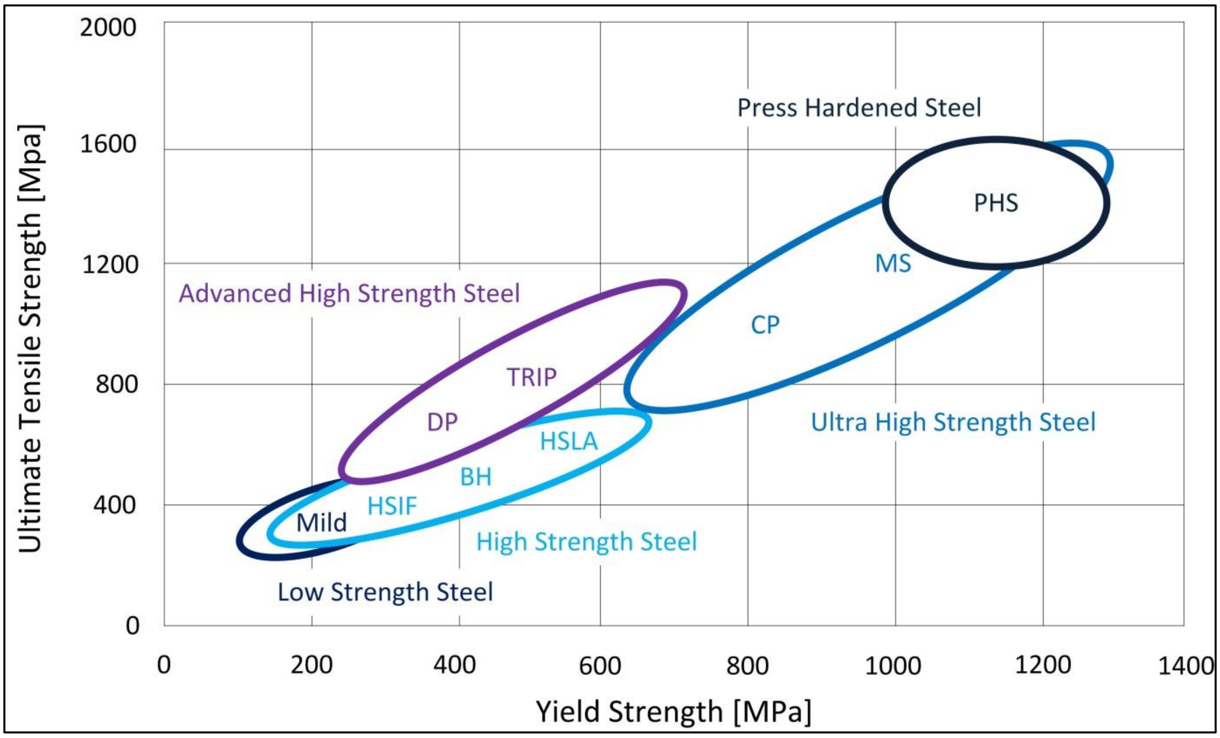

Figure 7-3: Metallurgical Steel Classes[206]

- Low Strength Steel

Low strength steel has minimum alloying elements and a very low carbon level which makes it soft and formable. Mild steel often serves as a baseline for comparing to other materials because it is cheap and widely used. Due to the low strength level it has a very good formability and is therefore used for a lot of applications in the car body structure and closures.[207]

- High Strength Steels (HSS)

High strength steels are one step above low strength steels and contain high strength interstitial free steels (HSIF), bake hardening steels (BH) and high strength low alloy steels (HSLA).[208]

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[206] Cf. Automotive Circle (2012a), p. 3, own illustration
[207] Cf. Tamarelli (2011), p. 19
[208] Cf. WorldAutoSteel (2009), p. 10

High Strength Interstitial Free Steels (HSIF)

High strength interstitial free steels have as the name says interstitial alloying elements. The carbon level is also very low which provides a good formability. They are widely used for complex deep drawing parts in automotive industry like for example the fender.[209]

Bake Hardening Steels (BH)

Bake hardening steels have a low strength in the initial condition. The main advantage is the special chemistry of this steel grade. That makes it possible that they get their final strength while paint baking on the already formed part. Therefore they are called bake hardening steels. Main applications for the automotive industry are parts like the door outer or hoods due to the increased dent resistance.[210]

High Strength Low Alloy Steels (HSLA)

High strength low alloyed steels are micro-alloyed steels which provide better mechanical properties. These grades are suitable for structural parts in the car body and as well as for suspension systems, reinforcements and so on. Due to their very good cold forming performance they provide cost effective solutions for many parts.[211]

- Advanced High Strength Steels (AHSS)

Advanced high strength steels include dual phase steels and transformation induced plasticity steels[212]

Dual Phase Steel (DP)

Dual phase steels can be hot or cold formed and is currently one of the most used AHSS. The range of application is very broad and especially in the car body structure used for beams and cross members as well as for rocker, sill and pillar reinforcements.[213]

Transformation Induced Plasticity Steels (TRIP)

This steel type has a transformation within its microstructure during the forming process. Due to this fact it is possible to maintain a relatively high formability while

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[209] Cf. Arcelor (2013a), p. 2
[210] Cf. Thyssen (2013), p. 1
[211] Cf. Arcelor (2013b), p. 2
[212] Cf. Automotive Circle (2012a), p. 10
[213] Cf. Tamarelli (2011), p. 21

achieving high strength after forming. TRIP steels are preferred for complex structural parts with a high deep drawing rate. A further advantage is that this steel also possesses a high bake hardening potential.[214]

- Ultra High Strength Steel (UHSS)

Ultra high strength steel includes complex phase steels and martensitic steels.[215]

Complex Phase Steels (CP)

Complex phase steels have already a very high tensile strength and the microstructure is very similar to TRIP steels but some additional alloying elements allow a higher strength. Due to this attributes common parts are B-pillar reinforcements and other structural pats.[216]

Martensitic Steels (MS)

Martensitic steel is known for its extremely high strength but this results in a, compared to the other steel grades already mentioned, relatively low formability. It is in most case roll formed and obviously used where high strength is critical in the body structure like the rocker panel or door intrusion beams. Because of tis high strength to weight ratio it is very cost effective and enables lightweight design.[217]

- Press Hardened Steels (PHS)

In contrast to the steel grades already mentioned so far this steel type is exclusively formed in hot condition above 930°C. Due to the quenching after the forming process the microstructure changes and provides a part with a very high strength. Press hardened steel allows producing parts with a high strength with complex shapes due to the good formability in hot condition.[218]

Figure 7-4 gives an overview of the described steel grades concerning the ultimate tensile strength over the elongation. The elongation decreases with increasing strength, therefore the elongation serves as a degree of formability and helps to understand why the formability of the different steel grades is decreasing the higher the strength is. Especially for press hardening the reason why this process includes a

[214] Cf. Thyssen (2007), pp. 2-4
[215] Cf. Circle (2012a), p. 10
[216] Cf. Kuziak/Kawalla/Waengler (2008), p. 109
[217] Cf. Tamarelli (2011), p. 25
[218] Cf. Fröber/Kösters (2002), p. 5

heat treatment can be easily explained. The initial strength of the blank is at around 450 MPa at an elongation level of 20%. After the process we reach a strength which can be above 1600 MPa.[219]

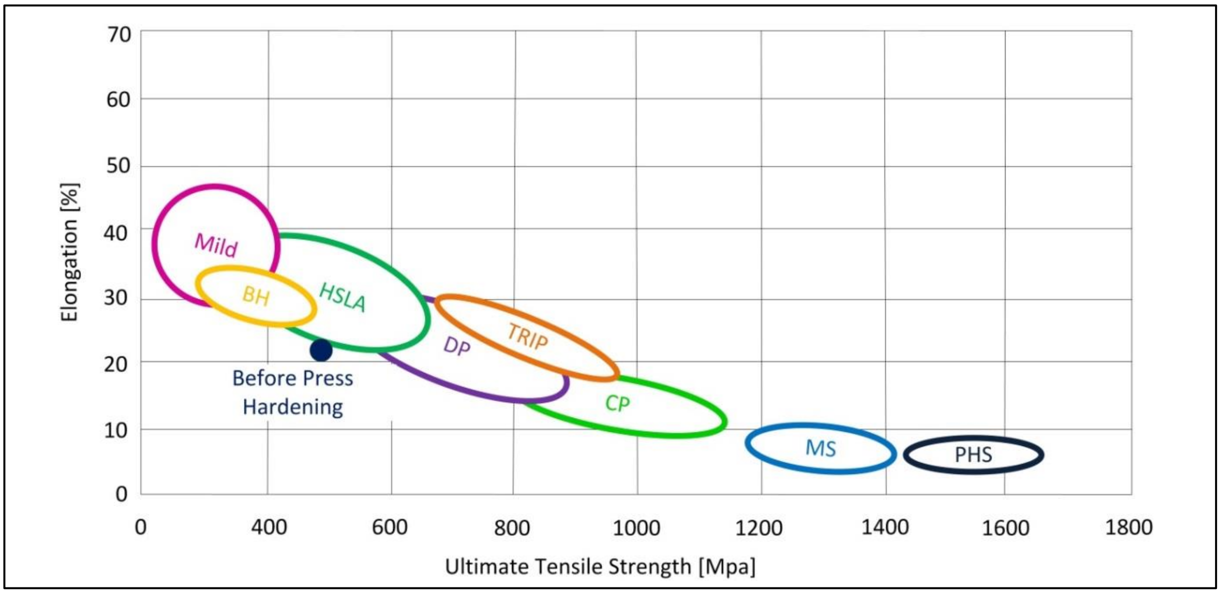

Figure 7-4: Schematic of AHSS[220]

7.4 Material Mix for the Body in White

After the definition of the material classification the next step was to compare the material mix for the body in white in the different markets. The purpose was to figure out the percentage of different materials of the total body in white mass to figure out if there will be changes in the future material mix.

7.4.1 Europe

Most of the data for the material mix in car body structures was available from European manufacturers as most of the conferences were held within Europe. The C-segment is the most representative one containing 11 models from 1995 till 2012 as shown in Figure 7-5.

[219] Cf. Fermér (2012), p. 3
[220] Cf. Fermér (2012), p. 3, own illustration

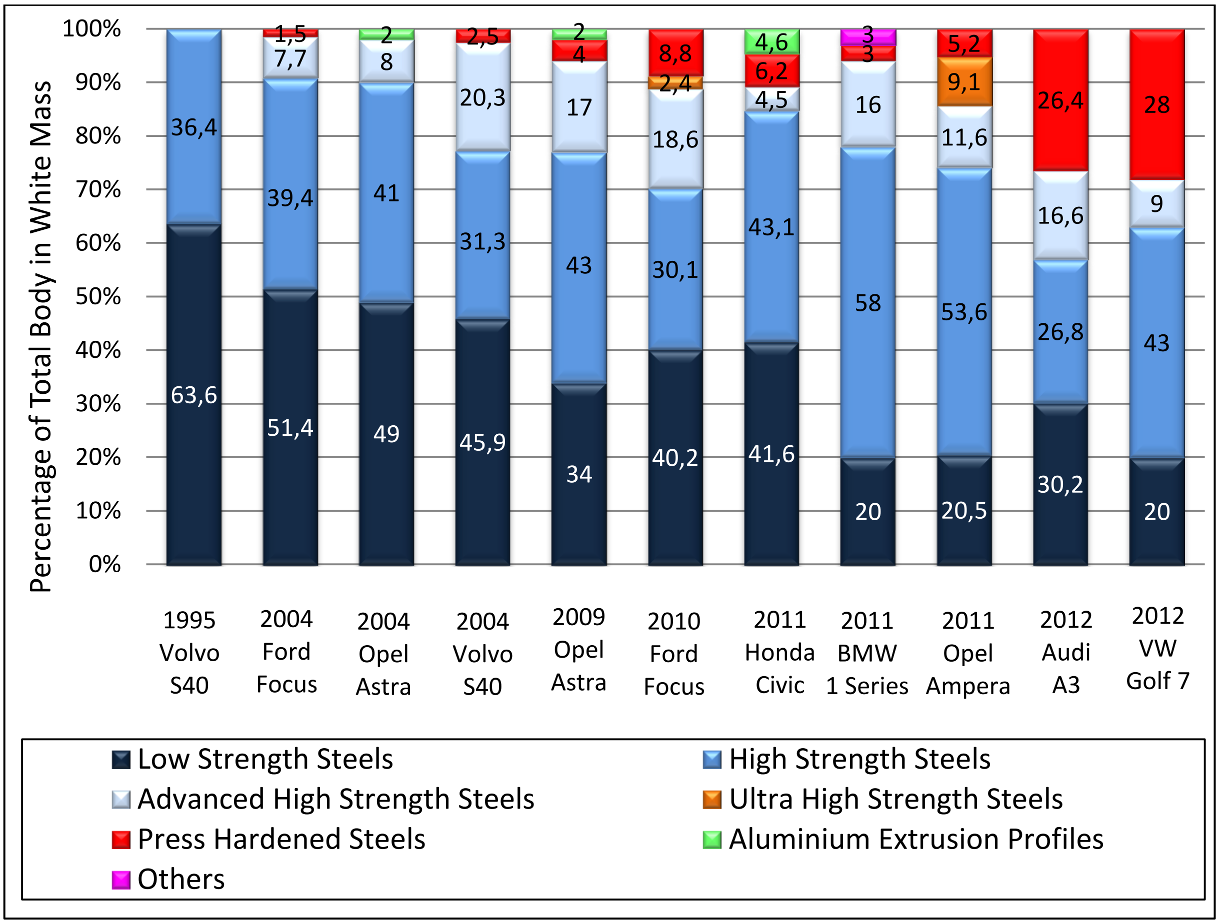

Figure 7-5: Material Mix of Body in White for the C-Segment[221]

The material mix for the body in white for the C-segment shows very well the dominating role that steel possesses within the volume production. It contains 3 Models (Volvo S40, Ford Focus, Opel Astra) where a comparison with the predecessor is possible. All 3 car manufacturers followed the trend of using more high strength (HSS) and advanced high strength steel (AHSS) grades at the expenses of low strength steels. The overall trend draws the same picture with an increasing content of HSS and AHSS. Continuing this development, the newest models also make use of more and more press hardened parts in their body in white. For example the models out of the Volkswagen Group as the Audi A3 and the Golf 7 build-up on the same platform and make use of more than 25% of press hardened parts. The use of steel grades with higher strength makes it possible to design parts with less material, for example thinner walls for a B-pillar, which results in reduced weight.[222]

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[221] Details and Sources in Appendix E
[222] ibidem

7.4.2 China

The Chinese market is expected to be a few years behind the development in Europe. On site visits in Shanghai helped a lot to draw much clearer picture. The first interview was at Shanghai Volkswagen (SVW).

7.4.2.1 Shanghai Volkswagen

The plant in Shanghai is one of the biggest Volkswagen plants in China with around 13000 employees. In a joint venture with Shanghai Automotive Industry Corp. (SAIC) the models Polo, Polo Classic, Santana, Santana Vista, Touran, Passat and the Skoda Octavia are build.[223]

The visit at Shanghai Volkswagen brought a better view to the future plans of the company in terms of utilized car body materials. Most of the new models will use the new platform, called "Modularer Querbaukasten" (MQB) in German, for C-segment vehicles. The material distribution shows a decrease in low strength steel which is the same trend as in Europe. The main statement through the whole discussion was that for future the amount of press hardened parts will increase over the whole product portfolio. An indicator what materials are used in the next models can be given by the launch of new models like the Golf 7 end 2013, the next Skoda Ocatvia in 2014, the Audi A3 in 2014 and one model with the internal codename A-Plus (a car for the C/D-Segment). All these cars will use the MQB platform as basis. Figure 7-6 shows the material mix of 3 models of SVW including the distribution for the Skoda Octavia which builds up on the MQB. The Volkswagen Lavida is one of the best-selling models of the group, but it still uses an old platform called PQ35 (which was also used by the Golf 5). The use of an older platform makes sense due to the affordability issues and is the reason for a different material distribution compared to the 2011 SVW Passat or the 2014 SVW Octavia. [224]

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[223] Cf. Volkswagen (2013), www.volkswagen.de/de/Volkswagen/nachhaltigkeit/Standorte/asien/shanghai.html, accessed 10th July 2013

[224] Discussion with Mr Zhao Chuanjun, Engineer for Body in White at SVW and Mr Gao Yifeng, Engineer for Stamping and Process Planning at SVW; Shanghai Volkswagen, 13th of May 2013, Shanghai

Table 7-1 provides an overview of the number of hot stamped parts in the body in white for selected models at SVW.

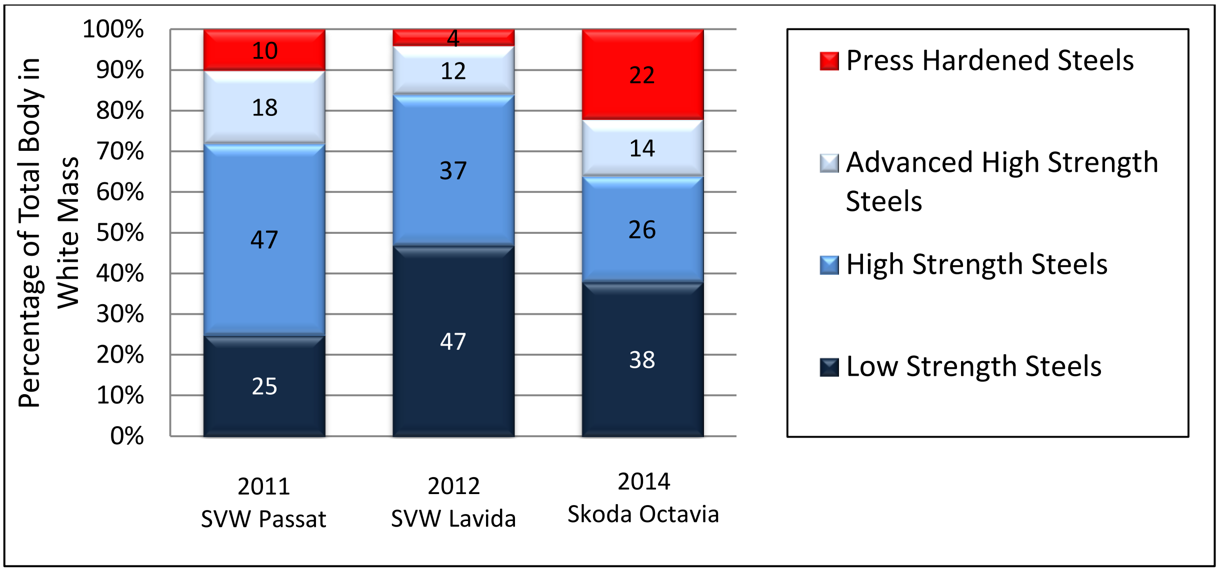

Figure 7-6: Material Mix for Body in White at SVW[225]

SVW Tiguan	6 parts
SVW *Santana*	7 parts
Skoda Yeti	4 parts
Skoda Octavia (MQB)	22 parts
A-plus (MQB)	20 parts

Table 7-1: Number Hot Stamping Parts at SVW[226]

As the MQB is Volkswagens new platform for the volume segment and it is expected that a lot of car models to come will build up on it, further information was needed. Press hardening is seen to play an important role in future car bodies. With the help of ASSAB (Associated Swedish Steel Aktiebolag) Shanghai it was possible to get a list of press hardened parts used for a Volkswagen model building up on the MQB platform. It also contains important information of the estimated tool steel need per part which is essential for the calculation of the tool steel potential. Table 7-2

[225] Discussion with Mr Zhao Chuanjun, Engineer for Body in White at SVW and Mr Gao Yifeng, Engineer for Stamping and Process Planning at SVW; Shanghai Volkswagen, 13th of May 2013, Shanghai

[226] ibidem

provides an overview of typical hot stamped parts for a body in white build using the MQB.[227]

Parts	Pieces	Estimated tool steel need [t]	
		Press Hardening	Blanking
central tunnel	1	4	0,4
cross member foot room upper	1	3,5	0,4
cross member foot room lower	1	3,5	0,4
longitudinal member under floor front (left/right)	2	0,7	0,1
longitudinal member under floor rear (left/right)	2	5	0,5
A-pillar reinforcement lower (left/right)	2	3,5	0,3
A-pillar reinforcement upper (left/right)	2	3	0,2
B-pillar reinforcement (left/right)	2	4,5	0,4
sill reinforcement (left/right)	2	3,5	0,3
rear seat heel reinforcement	1	3,5	0,4
cross member rear floor	1	3,5	0,4
front bumper beam	1	1,8	0,3
front door beam (left/right)	2	1,5	0,4
rear door beam (left/right)	2	1	0,3
Sum	22	42,5	4,8

Table 7-2: Hot Stamping Parts in Body in White using the MQB Platform [228]

The interview at Shanghai Volkswagen together with the information concerning the press hardened parts draws a very similar picture as the development for Europe already has shown. Steel will be the number one material in volume production over the next years and the use of high strength steels, advanced high strength steels and press hardened steels is increasing in future.

[227] Discussion with Mr Zhao Chuanjun, Engineer for Body in White at SVW and Mr Gao Yifeng, Engineer for Stamping and Process Planning at SVW; Shanghai Volkswagen, 13th of May 2013, Shanghai

[228] Discussion with Mr Eason Fan, Business Development Manager (Automotive), ASSAB Tooling Technology Co Ltd, 16th of May 2013, Shanghai

7.4.2.2 Pan Asia Technical Automotive Centre

The Pan Asia Technical Automotive Centre (PATAC) is an engineering and design joint venture between General Motors and Shanghai Automotive Industry Corp. It is one of the core development centres in the global General Motors (GM) network.[229]

At PATAC it was possible to gather information about the platforms Delta I, D2XX and D2UB. Delta I is a midsize platform used for the models Chevrolet Cruze and Buick Excelle in the Chinese market. D2XX is the new global midsize platform which competes directly with the Volkswagen MQB. XX in the nomenclature is just a placeholder for SC which stands for Chevrolet (e.g.: D2SC), SB which stands for Buick or SL for Cadillac. D2UB is a new platform developed for SUVs and crossover models. It is planned to introduce one new model in 2013 and 4 new models in 2014. All of them will use the new platforms. The material distribution for a car building up on these platforms is shown in Figure 7-7. PATAC didn't provide names for the planned models which will use these platforms.[230]

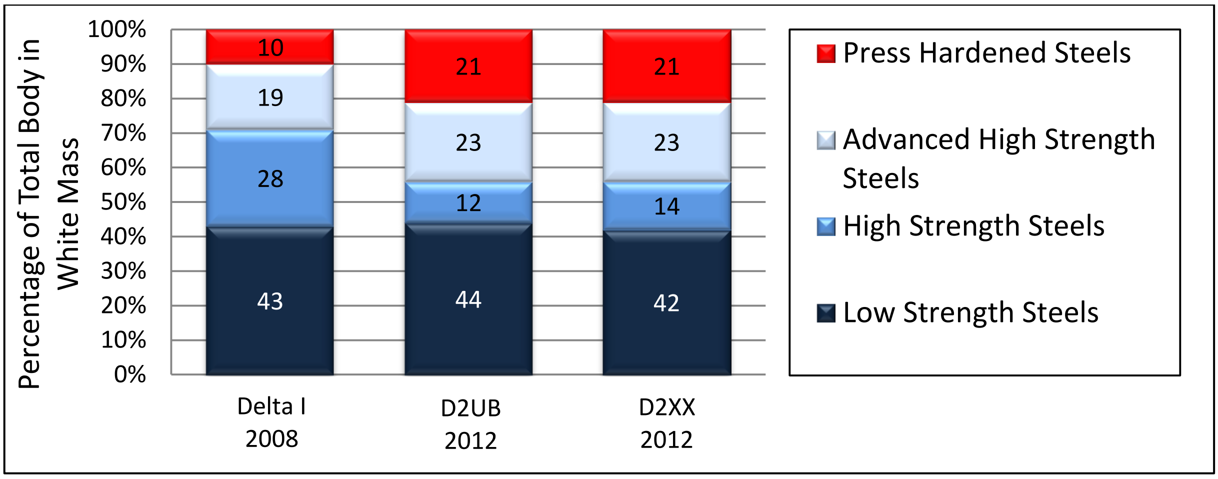

Figure 7-7: Material Mix for Body in White at PATAC GM[231]

The interview with the group manager from the body department at PATAC GM led to the same conclusion as for Volkswagen and shows a quite similar trend to the development figured out for Europe. Steel is the dominating material and the use of high strength steels, advanced high strength steels and press hardened steels is increasing.

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[229] PATAC (2013), www.patac.com.cn/, accessed 10th July 2013

[230] Discussion with Mr Qiao Dong, Body Upper Structure Engineering Group Manager at Department for Body and Exterior, Pan Asia Technical Automotive Center, 15th of May 2013, Shanghai

[231] ibidem

7.4.2.3 Magna Cosma International

Magna Cosma is supplying the automotive industry with body- and chassis-systems. The department for body structure systems is supplying parts including frame rails, floor pans, upper body pillars and body side systems.[232]

Magna Cosma is using the direct press hardening process for coated and uncoated sheets in the body structure. This was the first company in Shanghai were it was possible to get information concerning the die life. According to the die engineering department they do 200.000 shots for uncoated sheets and up to 500.000 shots for coated parts. Magna Cosma International is expecting a growing demand for press hardened parts in the next year but was not able to provide exact numbers.[233]

7.4.2.4 Outlook for China

The automotive companies in the Chinese Market, with the biggest market share for the two global OEMs General Motors and Volkswagen, will use an increased amount of higher strength steel grades and press hardened steels. This is a quite similar trend to the European market. Reasons for that are on the one hand the global for global production strategies of the global OEMs focussing more and more on a small number of platforms within on group. It doesn't make sense for the car manufacturers to make big changes in the layout of these platforms and the car body structure. Another point is that the Chinese joint venture partners of the global OEMs learn very fast from their experience and knowledge in using new technologies. Therefore they are most likely able to use manufacturing methods like press hardening much faster because they enter the learning curve at a much later stage.

Figure 7-8 shows a qualitative chart of the die cost development in press hardening over time at Volvo Cars. At the beginning we see that the cost is increasing because of the fact that more expensive tool steel is used with the purpose to increase die life and the lack of understanding the process which is obviously when applying a new technology. Over time improvements in the tool steel, the treatment of the die and a much better understanding of the process itself led to a cost reduction from 2002 to 2012 by 60 percent. Chinese manufacturers benefit from this knowledge and

[232] Cf. International Magna Cosma (2013), www.magna.com/capabilities/body-chassis-systems/products-services/body-systems/body-structure-systems, accessed 19th July 2013

[233] Discussion Mr Ian Chen, Die Engineer, Cosma Automotive (Shanghai) CO. Ltd., 15th of May 2013, Shanghai

experience which possibly enables them to enter the learning curve between the points A and B.[234]

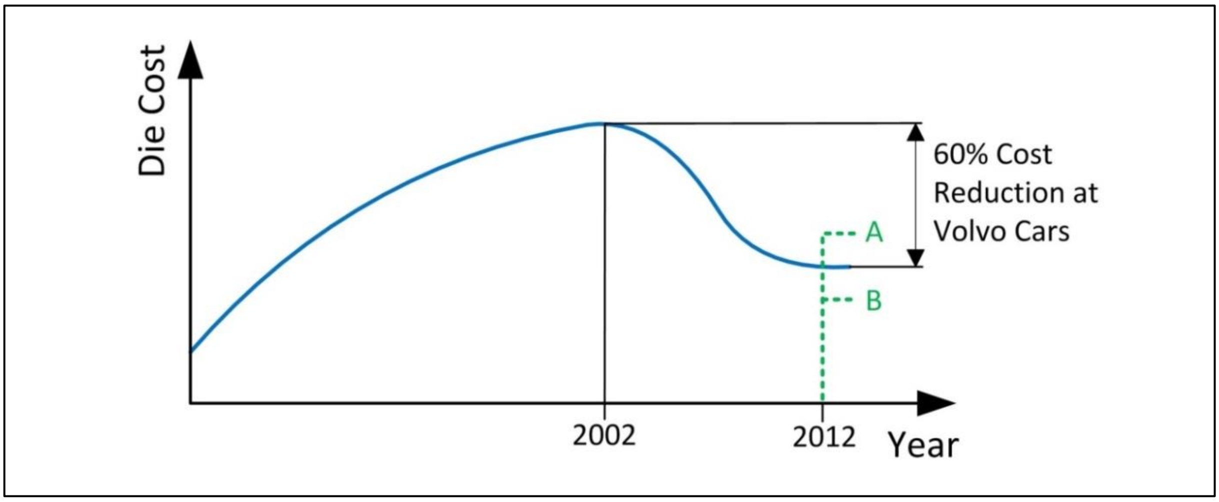

Figure 7-8: Qualitative Chart for a Learning Curve at Volvo Cars[235]

7.4.3 India

For the investigation of the Indian market also on site visits were planned. The main source of information for the body in white should have come from Maruti Suzuki and Tata Motors, but the already confirmed meetings have been cancelled.

According to Honda Cars India Ltd, today there is almost no use of high strength steel, advanced high strength steel or press hardened steel for passenger cars in the Indian market. The decisions if Honda will make use of other steel grades will be taken in Japan and therefore it was not possible to gather further credible information about the future plans.[236]

A discussion at Magna Cosma International led to the almost same result, they have no intention to make use of hot forming or make use of advanced high strength steels in the near future. Today they are just using mild steel and produce parts for Ford and Volkswagen.[237]

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[234] Discussion Mr Nader Asnafi, Vice President – Research and Development, Uddeholms AB, 26th of June 2013, Hagfors

[235] Discussion Mr Nader Asnafi, Vice President – Research and Development, Uddeholms AB, 26th of June 2013, Hagfors

[236] Discussion Mr Tripurari Srivastava, Executive-Power Train, Honda Cars India Ltd, 24th of May 2013, Rajasthan 301707

[237] Discussion Mr Marcel Varmaak, Tool Room – Incharge, Cosma International (India) Private Limited, 23th of May 2013, Tamil Nadu 603204

The meeting at Electropneumatics & Hydraulis (India) Pvt. Ltd., showed that this company, compared to the other visits, is probably one of the advanced companies in terms of manufacturing automotive components in India. They utilize hydroforming for manufacturing components like the front cross member, engine cradle and many more for General Motors, Volkswagen, Mahindra etc. In terms of stamping they are able to manufacture high strength steel but advanced high strength steel and press hardening is not in the portfolio yet. They will start to do some research on press hardening to build knowledge and experience within the next year.[238]

Godrej tooling is going into the same direction as the companies already mentioned. Actually they use no press hardening for structural parts of the car body and use sheet metal with a maximum tensile strength of 440 MPa. It is planned to use sheet metal with a tensile strength of 600 MPa in the near future. They see that there is a potential for sheet metal forming, but again no utilization of press hardening so far.[239]

The visits in India were different compared to China in that case that two of the main car manufacturers (Maruti Suzuki and Tata Motors) in India cancelled the meetings and therefore no information for the material mix in the body in white was collected. The discussions with suppliers to the Indian car industry indicate that the technology used for the body in white is far behind the development in China and obviously far afield of the European technology level. There is no intention to make use of advanced high strength steels or press hardened steels in mass production in the near future. It seems to be that it will take at least 10 years till the car manufacturing in India is on that level what we have in Europe today.

[238] Discussion Mr Reji K. Daniel, General Manager Component Manufacturing Division, Electropneumatics, 21th of May 2013, Pune 410 501

[239] Discussion Mr Pravin Deore, Assistant General Manager Press Tool Design, Godrej Tooling, 20th of May 2013,Mumbai 400 079

7.5 Future Material Development for Body in White

The future development in materials of the car body is a key topic when estimating the tool steel potential for automotive industry. A radical change in materials selection can have a significant impact on the business of Uddeholms AB.

As already mentioned the trend for the body in white as for the whole vehicle is going towards lightweight design. Basically lightweight design can be achieved by three different strategies as shown in Figure 7-9.[240]

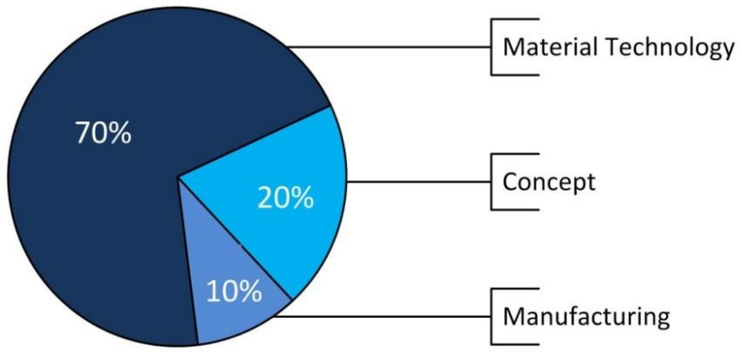

Figure 7-9: Strategies in Lightweight Design and their Potential[241]

Material technology has the highest potential for weight saving with around 70 percent, followed by concept lightweight design and manufacturing methods. As the material technology is accounting for the highest potential and has a big impact on the tool steel selection the focus is put on this area.[242]

The choice of the proper material is a basic question in car body design. It should always be the right material in the right place for the intended purpose. To achieve this, a lot of factors play a role. There is first the question of how much weight saving can be achieved by the use of an alternative material compared to the conventional one. Further the part manufactured out of the lightweight material has to be able to provide a certain level of strength to pass the safety tests, in other words the crash performance must be sufficient. The last and in most case crucial question is, what are the costs. Materials like carbon fibre reinforced plastics still have too high costs

[240] Cf. Füller (2012), pp. 7-8
[241] Cf. Füller (2012), p. 8, own illustration
[242] Cf. Füller (2012), p. 8

for production and manufacturing to be applied in mass production, even if they have considerable advantages in comparison to the conventional materials.[243]

7.5.1 Weight Saving Potential

Conventional steel was the dominating material for car bodies in the volume segment up till now. The question is if this is still the case for the next ten years. The evaluation of the material mix in current models showed already an increase in the used steel grades with higher strengths to reduce the material input for the parts and further save weight. This optimised steel design still has a potential for improvement up to 15 percent compared to conventional steel. Aluminium enables a weight saving up to 40 percent, Magnesium up to 50 percent and carbon fibre reinforced plastics up to 60 percent. Figure 7-10 illustrates the weight saving potential of several lightweight materials compared to the conventional steel design by maintaining the same function of the part.[244]

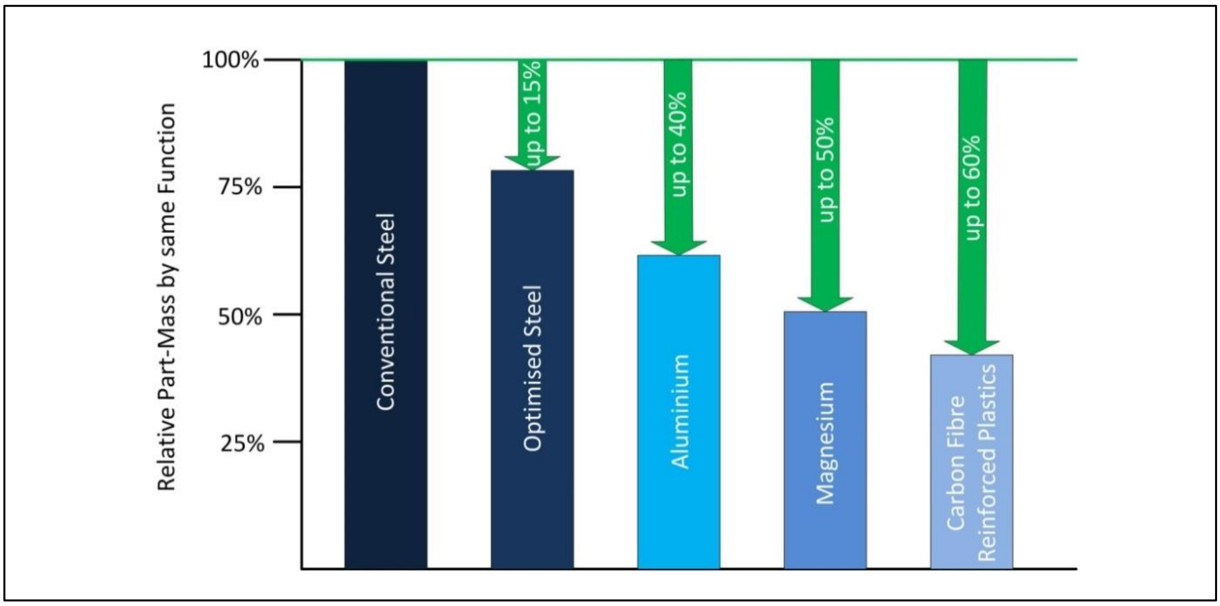

Figure 7-10: Weight saving Potential by Material[245]

[243] Cf. Klein (2009), p. 4
[244] Cf. Leohold (2012), p. 24
[245] Cf. Leohold (2012), p. 24, own illustration

7.5.2 Costs

Costs are the determining factor for or against the usage of lightweight materials. Basically there is a direct connection between the intended weight of the car body and the cost development. As a general rule the manufacturing costs increase with a higher degree of lightweight design. Reasons for this fact are the higher engineering-costs for design, calculation and testing of the lightweight concept, the in general higher material-costs and at last the higher costs for manufacturing due to the higher tool- and process-costs.[246]

Figure 7-11 compares the cost drivers for different lightweight materials, material-costs, manufacturing-costs and the costs for general surcharges increase using materials with a higher lightweight potential.

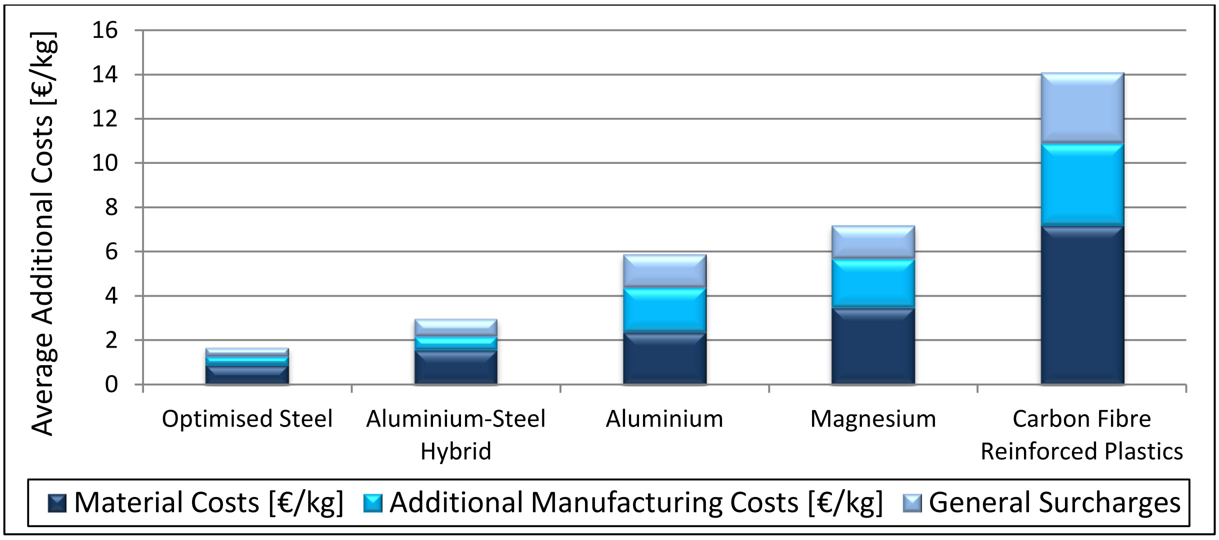

Figure 7-11: Cost Comparison of Lightweight Materials[247]

The comparison shows the additional costs per saved kilogram compared to conventional steel. Optimised steel structures have the lowest penalty at around 1,8 €/kg going up to 14 €/kg for carbon fibre reinforced plastics.[248]

How much Euro per saved kilogram an automobile manufacturer is willing to pay is depending on the market segment. For the volume segment the limit is lower than for high class premium vehicles. For structural parts 5 €/kg are an accepted value whereas 8 €/kg are the absolute limit for the C-/D-segment.[249]

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[246] Cf. Klein (2009), p. 4
[247] Cf. Rennet (2013), p. 10, own illustration
[248] Cf. Rennet (2013), p. 10
[249] Cf. Auto und Verkehr - Ingenieurgesellschaft (2012), p. 11

7.5.3 Trend for the Body in White Material Mix

Car manufacturers are focussing more and more on lightweight design and therefore the use of alternative materials is to contemplate, but there are still a lot of limiting factors which restrict or delay their economic application. On the one hand car manufacturers are just willing to pay a certain amount of money per saved kilogram. On the other hand today's production infrastructure in the volume segment, like machines, manufacturing lines and many other aspects are designed for steel bodies. Another point is that the production processes for several materials like carbon fibre reinforced plastics are still not applicable to mass production. Figure 7-12 shows a scenario for the development in future car body structures. In segments with a low production volume alternative materials are most likely to establish faster because the customers willingness to pay more for an innovative product. For the volume segment the market in Europe is still dominated by steel bodies and there will be room for improvements by using optimised steel structures. Beyond that a smart multi material mix for high production volume can be the solution for lightweight design in conformity with the economic aspects. Nevertheless steel will even there account for a significant portion of the mix.[250]

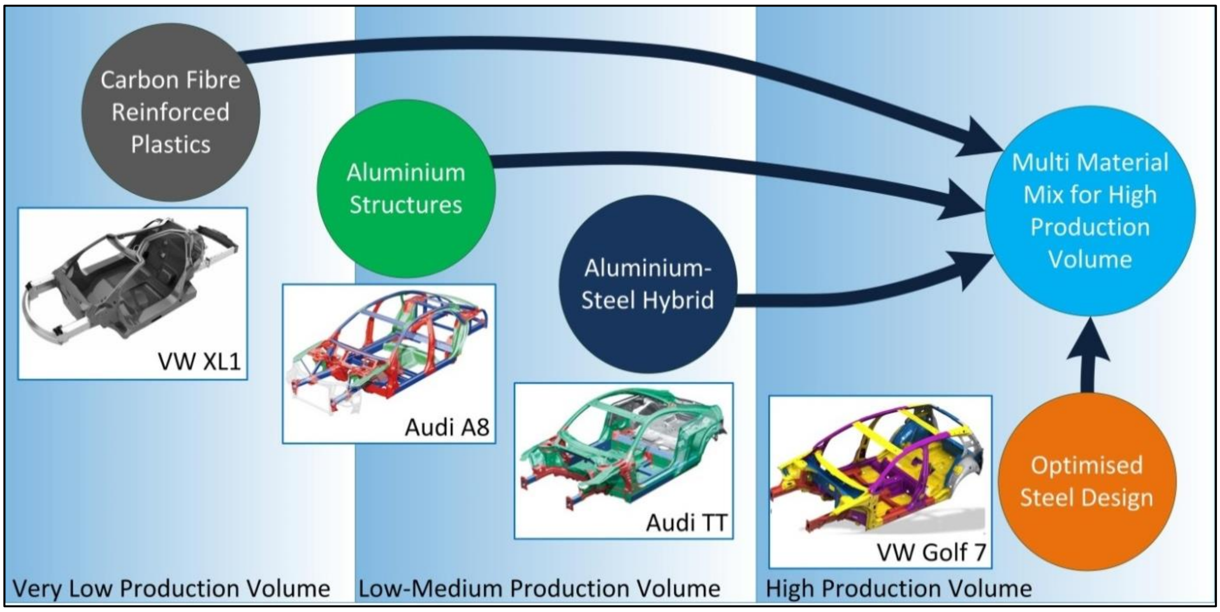

Figure 7-12: Future Car Body Structures[251]

[250] Cf. Leohold (2012), p. 59
[251] ibidem

7.5.4 Press Hardened Parts

The topic of car body materials is very broad and complex that it was necessary to take a decision and make some restrictions for the final calculation of the tool steel potential. The decision was to focus on press hardened parts for the further investigation. This is based on two main reasons. At first it is expected that the content of press hardened parts in the car body is increasing as already found out which can be underlined by the following Figure 7-13.

Over the last 14 years the amount of press hardened parts at BMW increased steadily. The purple line indicates the average development whereas the dots show the amount in particular models. It is not surprising that the models above the purple line are mainly cars out of the E- and F-segment like the 5 series and 7 series. BMW is expecting that this trend continues within the next years. This is obvious because the approach by car manufacturers is that new technologies are introduced first in the high price segments and if they have proven as right and successful they are introduced to the volume segment.[252]

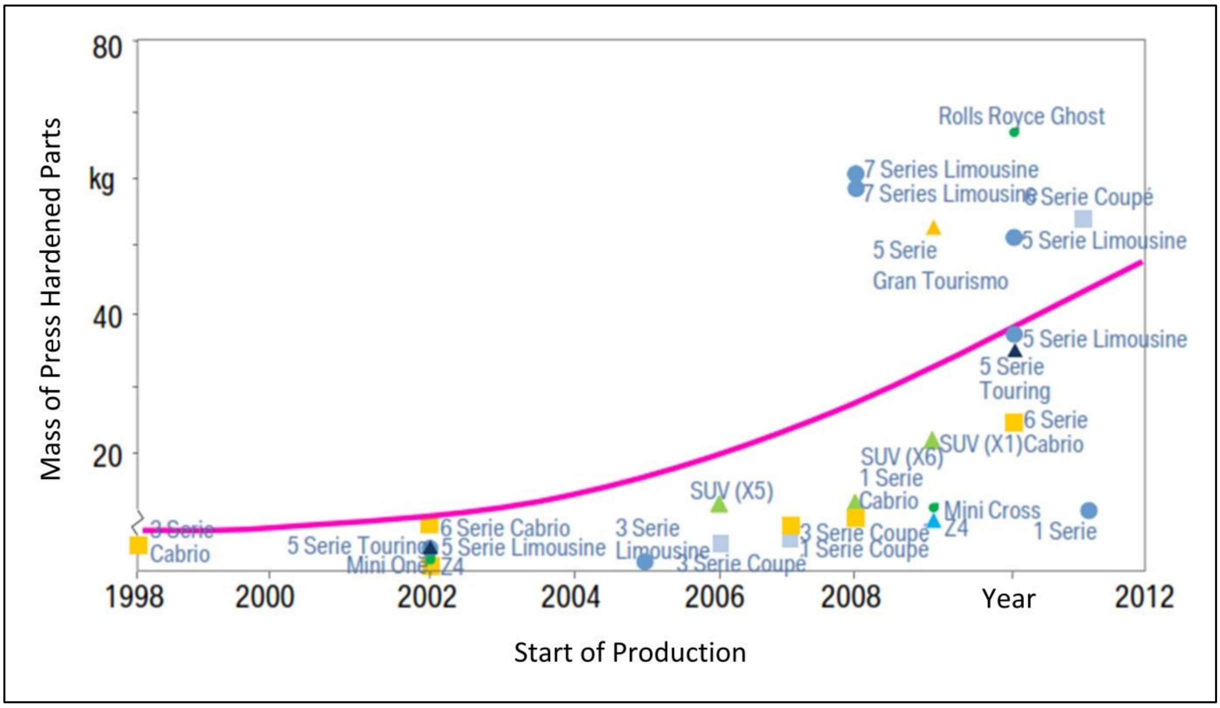

Figure 7-13: Development of Press Hardening at BMW[253]

[252] Cf. Süß (2012), p. 24
[253] ibidem

The second reason is the cost factor. Hereby a very meaningful example calculated by Volvo Cars should serve as an example.

The comparison of press hardening and cold forming is carried out by a calculation of the total part costs for the Volvo V40 (start of production 2012). The total mass of press hardened parts in this car is 62 kilogram. The question was how big is the difference if these parts, now manufactured in press hardening, were made with cold formed steel by maintaining the same level of safety and part function. The constraints for this calculation are that material utilization, thickness scale factor, steel cost and the material cost of total cost are estimations and the scrapping is not included. The thickness to scale factor means that for the same part with same properties around one third more material mass is necessary due to the lower strength of the cold formed part.[254]

Table 7-3 shows the results of the calculation.

	Press Hardened Steel	Cold Formed Steel
Type of Production	In-House Production	In-House Production
Material Utilization	70,00%	50,00%
Thickness Scale Factor	1	1,33
Steel Cost [€/kg]	1	1
Part Mass [kg]	62	82,7
Blank Mass [kg]	88,6	165,3
Material Cost [€]	88,6	165,3
Material Cost of Total Cost	65,00%	75,00%
Total Part Cost [€]	136,3	220,4
Mass vs. Cold Formed	-20,7	
Cost vs. Cold Formed	-84,2	

Table 7-3: Part Cost Comparison Press Hardening and Cold Forming[255]

[254] Cf. Fermér (2013), p. 7
[255] ibidem

The material utilization for cold formed parts is lower due to the fact that this steel is also used for other parts in the car, for example smaller parts which produce more scrap in the end. It cannot be narrowed down just to the parts which are now produced with press hardening because it makes no sense to purchase the cold formed steel separately for these structural parts which are now produced in press hardening. Bigger structural parts produced less scrap and therefore the material utilization is higher for press hardening.[256]

The conclusion is that in the end the press hardened parts are cheaper and lighter. For the body in white (BIW) the overall weight reduction due to the use of press hardening steel is around 20 kilograms. These advantages underline why press hardening is a technology which will be used by an increasing number of car manufacturers. As the trend for the body in white material showed us that the future will be a smart material mix, the question is if there is a limit for press hardened parts in the car body. This information is important to estimate the upper limit of press hardened parts for calculating the tool steel potential.[257]

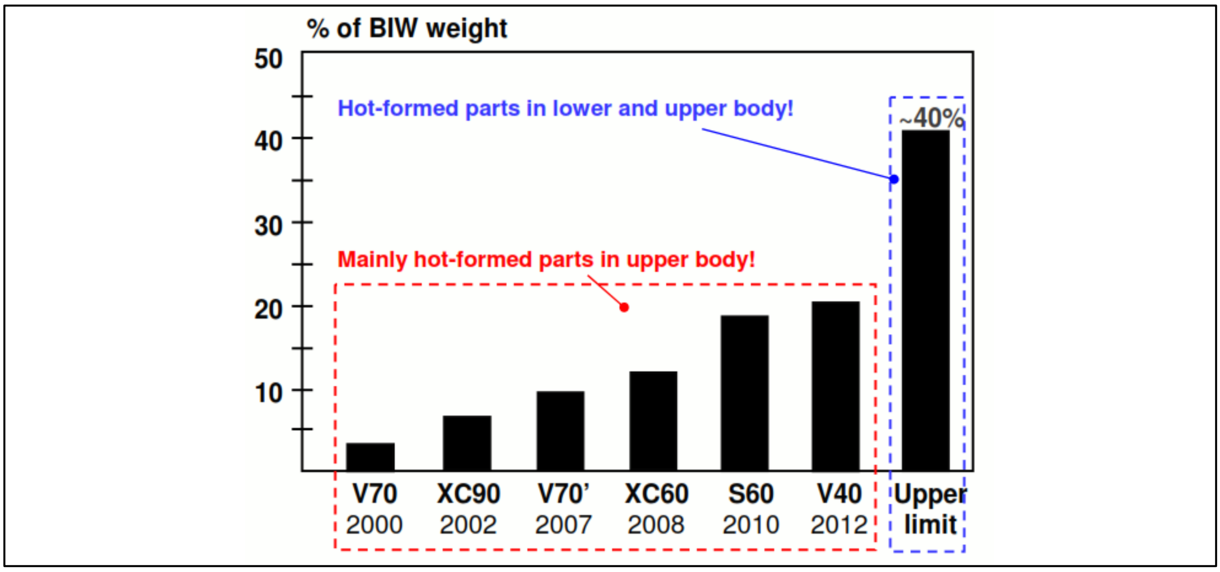

Figure 7-14: Limit for Press Hardened Parts in the Body in White - Volvo Cars[258]

According to Volvo Cars the maximum amount of press hardened parts within the body in white is at around 40 percent of the body in white mass.[259]

[256] Discussion Mr Nader Asnafi, Vice President – Research and Development, Uddeholms AB, 14th of August 2013, Hagfors
[257] Cf. Fermér (2012), pp. 3-4
[258] Fermér (2012), p. 4
[259] ibidem

The question, where do you see the limit of the weight percentage of hot formed steels that will be used in future car bodies, was asked at the conference Materials in Car Body Engineering 2012. The result is shown in Figure 7-15 where most of the experts expect that the amount of press hardened parts is between 15 to 35 percent of the body in white mass.[260]

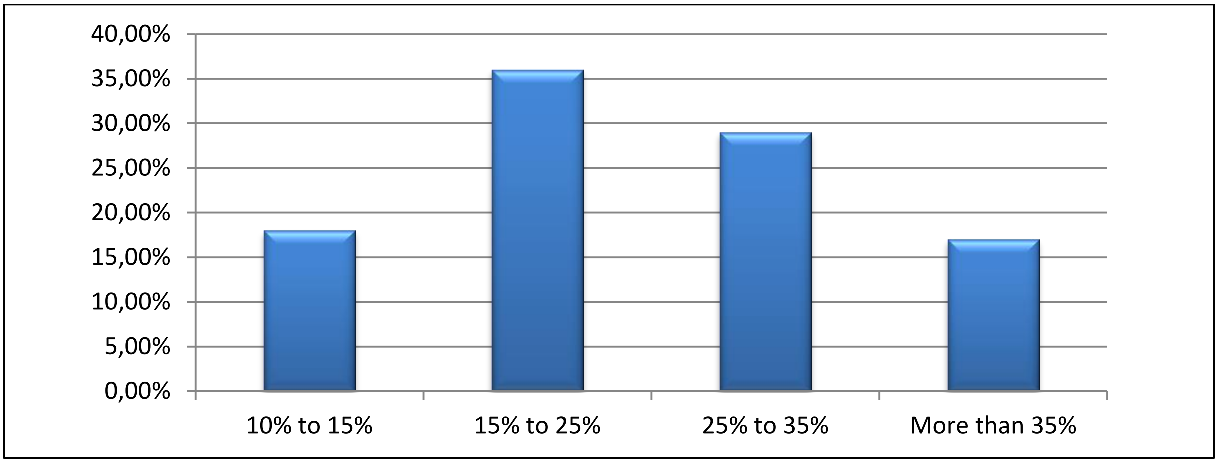

Figure 7-15: Limit for Press Hardened Parts in the Body in White - Survey[261]

For the further calculation of the tool steel demand an average value of 30% serves as basis.

7.6 Conclusion

The investigation of the car body materials showed very well that for future production in the volume segment steel will still play a dominating role. Due to the changing strategies in production, going to more and more models which base on the same platform, the diversity in different designs for the car body structure will decrease. As the car body itself is a huge topic the restriction was made to focus this calculation of the tool steel demand on press hardening. A consequence of the decision is that the Indian market is not considered for the further calculation because of two main reasons. First is the expectation that press hardening, for the near future, will play a minor role in the Indian automotive industry due to a lack of technological knowledge. Second is that the information gathered is not sufficient enough to make a well-founded statement. For the European and the Chinese market the information basis is broader and allows a more accurate prediction.

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[260] Cf. Automotive Circle (2012b), p. 1
[261] ibidem

8 Forecast of Tool Steel Potential

The forecast builds the final part of the thesis. All kinds of information gathered up to that point contribute to calculate the tool steel market potential for press hardening. The first step of the forecast was to create a procedure how the calculation can be conducted.

8.1 Method for Calculation

To achieve an accurate prediction a lot of information from different factors contribute to the result. So it was necessary to figure out which parameters influence the tool steel demand. The approach for the calculation of the annual tool steel demand is shown in Figure 8-1.

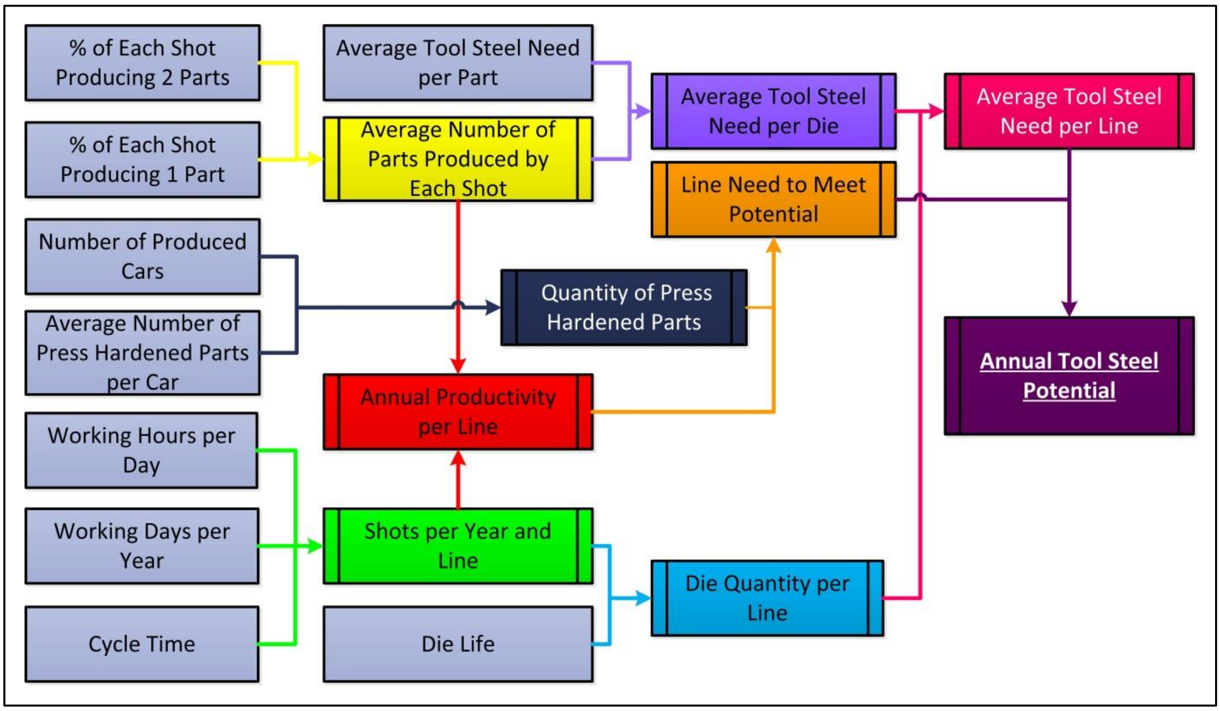

Figure 8-1: Calculation Scheme

The working days per year, working hours per day and the cycle time for the process lead to the average number of shots per year and line. The number of produced cars together with the average number of press hardened parts gives the quantity of press hardened parts. The percentage of each shot producing 1 or 2 parts leads to the average parts produced by each shot. The reason for using such a factor is that more and more dies are double cavity dies which produce 2 parts per shot. For example within one pressing step the B-pillar for the right and the left side is produced. The trend in future is even to make use of dies using more than two cavities.

The average number of parts produced by each shot and the shots per year and line result in the annual productivity per line. This productivity combined with the quantity of press hardened parts gives the line need to meet the potential production. The average tool steel need per part and the average number of parts produced by each shot result in the average tool steel need per die. The shots per year and line combined with the die life gives the quantity per line. This number of dies per line together with the average tool steel need per die results in the average tool steel need per line and further with line need to meet the potential production the annual tool steel demand can be calculated. Appendix C and D contain the whole calculation of the tool steel potential for the European and Chinese market out of which the charts were developed.

What is important to mention in this calculation is that the cycle time, working days per year, working hours per day and the percentage of each shot producing 1 or 2 parts just influences the line need to meet the potential production. Direct influence on the tool steel demand have the die life, the average tool steel need per part, the number of produced cars and the average press hardened parts per car.

The number of produced cars was separated into the origin of the manufacturer to consider that they use a different amount of press hardened parts per car. It is divided into European, North American, Chinese, Japanese, Korean and other manufacturers. European cars use the most press hardened steel in their cars followed by the North Americans, Korean, Japanese and Chinese manufacturers.

All these factors contribute to the calculation of the tool steel potential until 2028. To consider is that it becomes more and more difficult to calculate the potential the farer we go into future. All parameters taken into account for the calculation are on their part influenced by a lot of other factors and therefore the scenario technique was used to create a funnel of possibilities. Environmental factors which influence the development of the tool steel demand in press hardening:

- Development in car sales and production
- Number of press hardened parts per car
- Type of die: single-, double- or more-cavity dies
- Tool steel need per die
- Die life
- Overall economic development
- Alternative materials

8.2 **Europe**

The tool steel potential for press hardened parts is shown in Figure 8-2. In terms of market share domestic manufacturers have a clear ascendance and due to the fact that most of the information is coming from European car manufacturers the estimations have a good foundation. The political situation in Europe is quite stable and therefore no big variations are expected because of changes in law.

The prediction for the tool steel potential shows a positive trend over the next years. The expected slight growth in car production as well as the increased use of press hardened steel lead to a higher demand in tool steel in this area. An important point concerning the production of press hardened parts is the number of press lines to meet the potential production. This factor can be limiting the tool steel demand because there are not enough press lines available for the production. So the infrastructure for production is a critical factor which should be considered.[262]

The scenario model tries to eliminate uncertainties in the research area to create a scope in which the tool steel potential can develop. The high-development bases on a higher growth in car production, an increased use of press hardened parts and the assumption that it is possible to deal with all the problems like the sufficient number of press lines compared to the baseline scenario. The low-development uses the inverted approach and also assumes that press hardened steel will be replaced by alternative materials earlier than expected for the baseline scenario. The use of alternative car body materials can be the case earlier in Europe than in China as the market is technological more advanced.

[262] Details and Sources in Appendix C

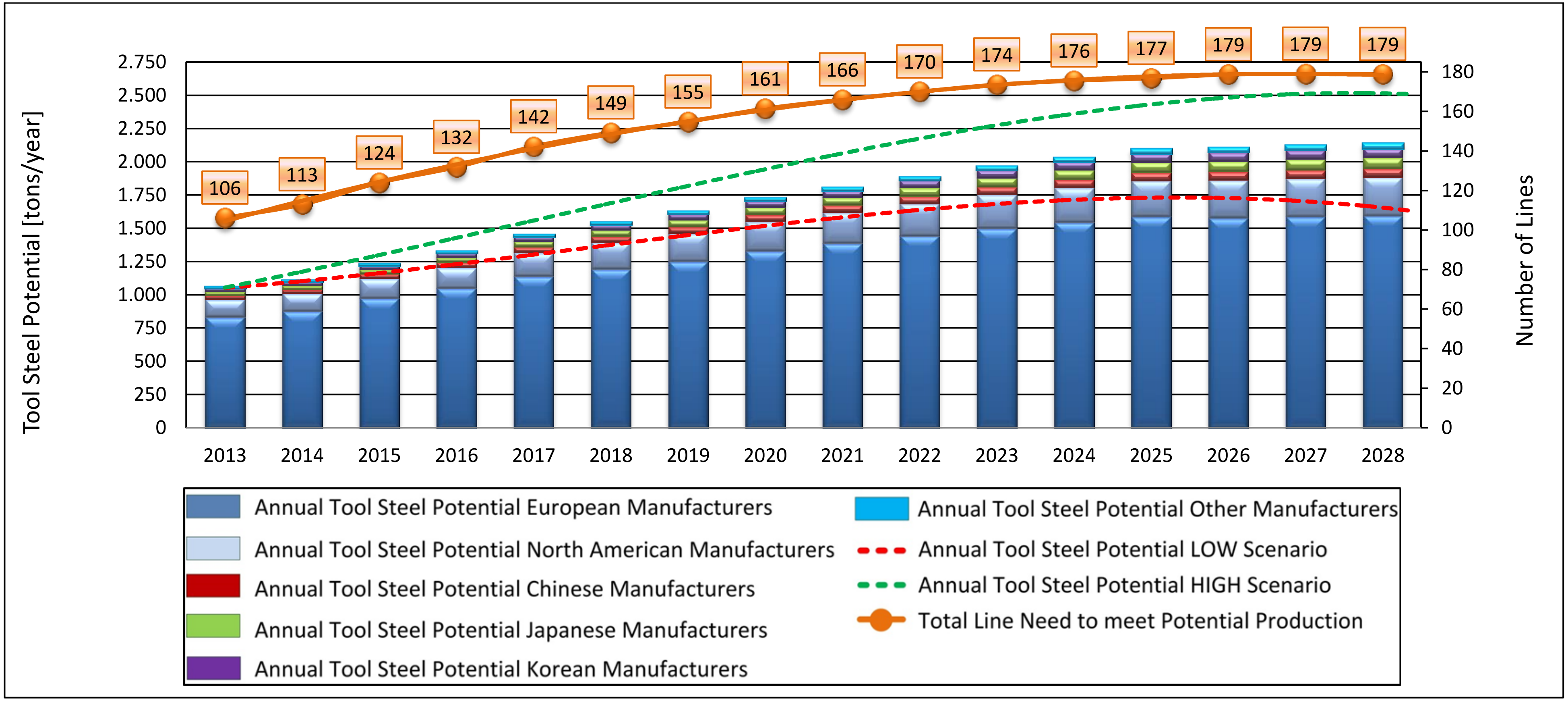

Figure 8-2: Tool Steel Potential for Press Hardening in the European Market[263]

[263] Details and Sources in Appendix C

8.3 **China**

The market potential for China is shown in Figure 8-3. The overall trend is positive and brings an increase in the use of tool steel for press hardened parts. The distribution of the potential on the origin of the manufacturers is different to Europe as European and Chinese manufacturers are leading, followed by North American, Japanese and Korean. As the Chinese manufacturers account for a considerable amount of the tool steel potential it will be of high interest for the ASSAB teams in China to figure out how to get in touch with Chinese car manufacturers. Another important point is to know which requirements they have for their tool steel selection. Will they do in-house production or do they give the contracts to suppliers? If they give it to an external supplier will they have the same approach as global OEMs like Shanghai Volkswagen? Shanghai Volkswagen for example is more or less controlling the whole supply chain and dictates the supplier which tool steel they have to use. So it is necessary to convince SVW that Uddeholms tool steel is on a list of possible tool material for press hardened parts. That is an important question to find out if creating a strategy for the Chinese market.[264]

The approach using the scenario technique is the same when it comes to the high and low development. To consider is that the political situation in China is different to Europe that changes in law or regulations can happen quickly without prior notice. The limiting factor in terms of press lines is stronger in China as it is expected that the infrastructure is not able to meet the potential.[265]

According to an estimation made by Arcelor Mittal there will be around 90 lines running in China around 2017. That would be just half the number which is calculated to meet the tool steel potential. Discussions with the technical team of ASSAB China showed that they expect around 600 running press hardening lines globally in 2017, where they expect around one third of that in China. So there is a huge difference between those two statements. [266]

Table 8-1 gives an overview what ASSAB Shanghai knows about the press hardening lines already running and what is planned by the listed companies. The companies in the table are all suppliers to the automotive industry, but as it shows

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[264] Details and Sources in Appendix D
[265] Discussion with Mr Eason Fan, Business Development Manager (Automotive), ASSAB Tooling Technology Co Ltd, 16th of May 2013, Shanghai
[266] Uddeholm Internal Presentation, Jerker Andersson, Business Developer Hot Work Tool Steel

there is quite a big lack of information (most fields are named as unknown) what is planned in terms of press hardening lines in future. Actually the numbers are very low and don't fit to the estimation of around 200 lines which should run in 2017 mentioned above. So it is very important to get in contact with these companies and try to find out what their future plans are and how Uddeholms AB can benefit from that. Also the manufacturers of the press line itself like Schuler or AP&T are a main source of information.

Group	Press line manufacturer	lines now (2012)	lines in building	totally planned
Benteler	Schuler	6	0	unknown
Gestamp	Schuler	5	3	11
Cosma		4	0	unknown
Baosteel	AP&T	1	0	2
Shanghai SSDT	Schuler	1	0	2
Shanghai Yifeng	AP&T	0	2	4
Dongfeng TQM	Fagor	0	1	4
Shanghai Bohui	Fagor	0	1	unknown
Starq Y-tec	Japnese	0	1	unknown
Hubei Yongzhe	AP&T	0	1	unknown
Hebei Linyun		0	1	unknown
Changchun Fufeng		0	1	unknown
Great Wall	AP&T	0	1	4
Shanghai Jinyong		0	1	unknown
Tianjin Yuao		0	1	unknown
Tianjin Shunda		0	1	unknown
Changchun Beite		0	1	unknown

Table 8-1: Press Hardening Lines in China 2012[267]

[267] Mr Eason Fan, Business Development Manager (Automotive), ASSAB Tooling Technology Co Ltd

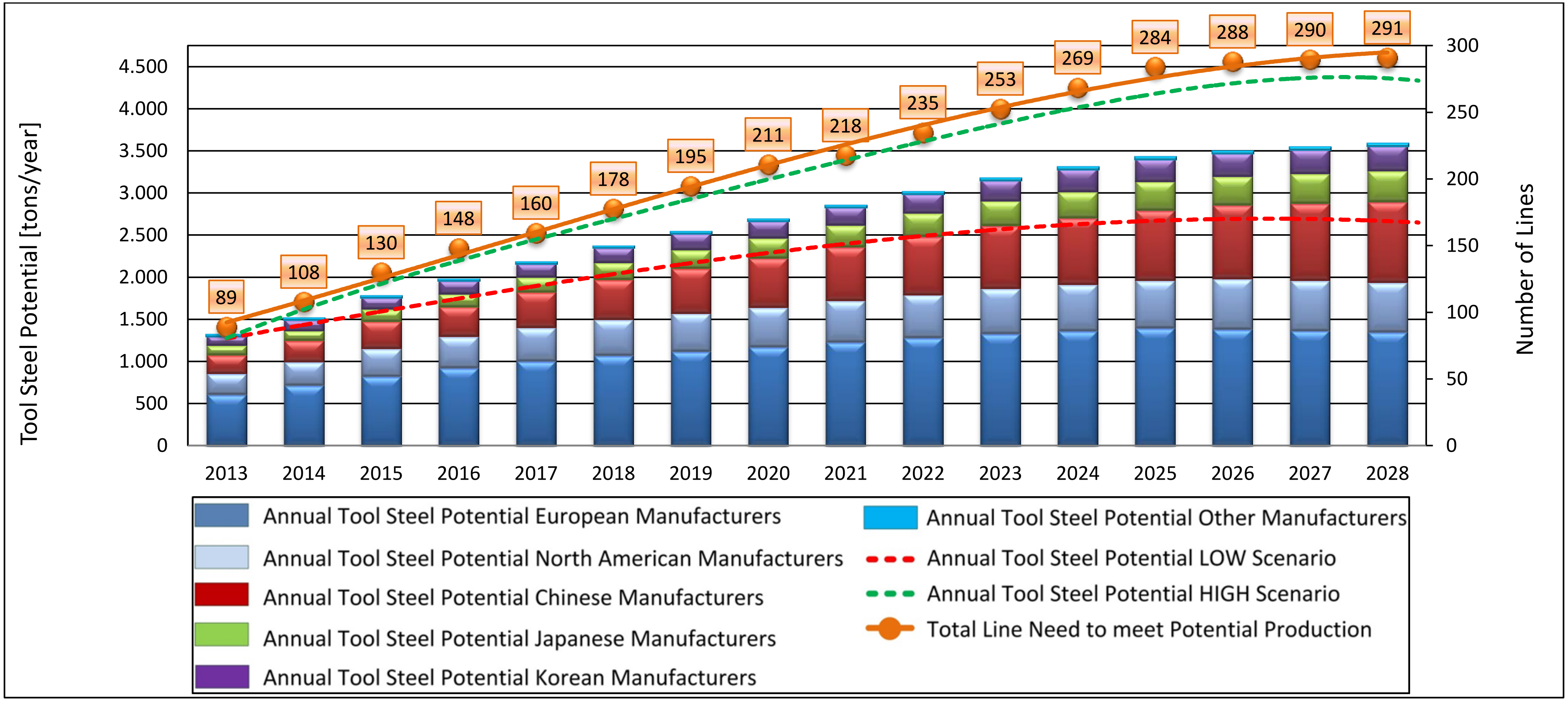

Figure 8-3: Tool Steel Potential for Press Hardening in the Chinese Market[268]

[268] Details and Sources in Appendix D

8.4 Conclusion and Outlook

The forecast for the press hardening tool steel potential is overall positive and it is expected that the demand will increase in Europe as well as in China. For both regions the trend to lightweight design leads to an increase in press hardened part for the car body. An important question to Uddeholms AB in this connection is how big the companies share can be at this potential. There are a lot of questions to be answered like: Which companies are potential customers for Uddeholms AB in Europe and China? How is the tool steel selection done in case of press hardening by these companies? Are the requirements to the tool for every part manufacturer the same or are they different in the several regions? Is it necessary to develop new steel grades to meet these requirements or are the existing grades fulfilling it sufficiently? For example is Europe going more for the expensive high quality tool steel grades and is China more price sensitive? Does the company have a proper sales strategy in the different markets? What are Uddeholms competitors planning? This is a collection of question which should be answered when trying to get more business in the tool steel market for press hardening.

All these are parameters, and for sure there are a lot more, which can contribute to work out a strategy how the company should act in the press hardening market within the next years. A well-defined strategy which is tailored to the customers expectations is of outmost importance to increase the market share.

Further it is necessary to monitor the developments in the car body sector and the powertrain development constantly to be prepared if the trend is going into another direction as expected, which can have a big impact on the tool steel selection and therefore on the business of Uddeholms AB. Also for the Indian market it is recommended to watch the development to be right in place when the car industry starts to use more advanced car body materials as it is expected that they follow the trend in Europe, but no one really knows today when this is the case.

Furthermore under observation should be the political development which affects the car industry. Governmental subsidies for alternative propulsion systems like the electric car can have a significant impact on the car body as well. For China there are quite often the rumours that the government will pass a law which privileges electric vehicles in the megacities to deal with the increasing air pollution. Also in discussion is if the restriction to measure just the tailpipe emissions for CO_2 regulations will be a long term approach. It can be the case that the overall product life cycle will be considered for measuring the CO_2 emissions of future cars, including the emissions which emerge during the production (beginning at the raw material till the finished vehicle) and the end of life. These factors can affect the selection of car body materials and obviously the tool steel business in that area.

To make the actual forecast more accurate and improve the results it is recommended to gather more information in terms of die life, because this parameter has a significant influence on the calculation. Questions like the development of the die life over the next years as well as how many parts can be produced by one shot are of outmost importance. Further the calculation should be adopted to changes and constantly to keep it always up to date.

Summarized the outlook for press hardening tool steel is quite positive and together with an well selected strategy it should contribute to a positive development of the hot work tool steel business of Uddeholms AB.

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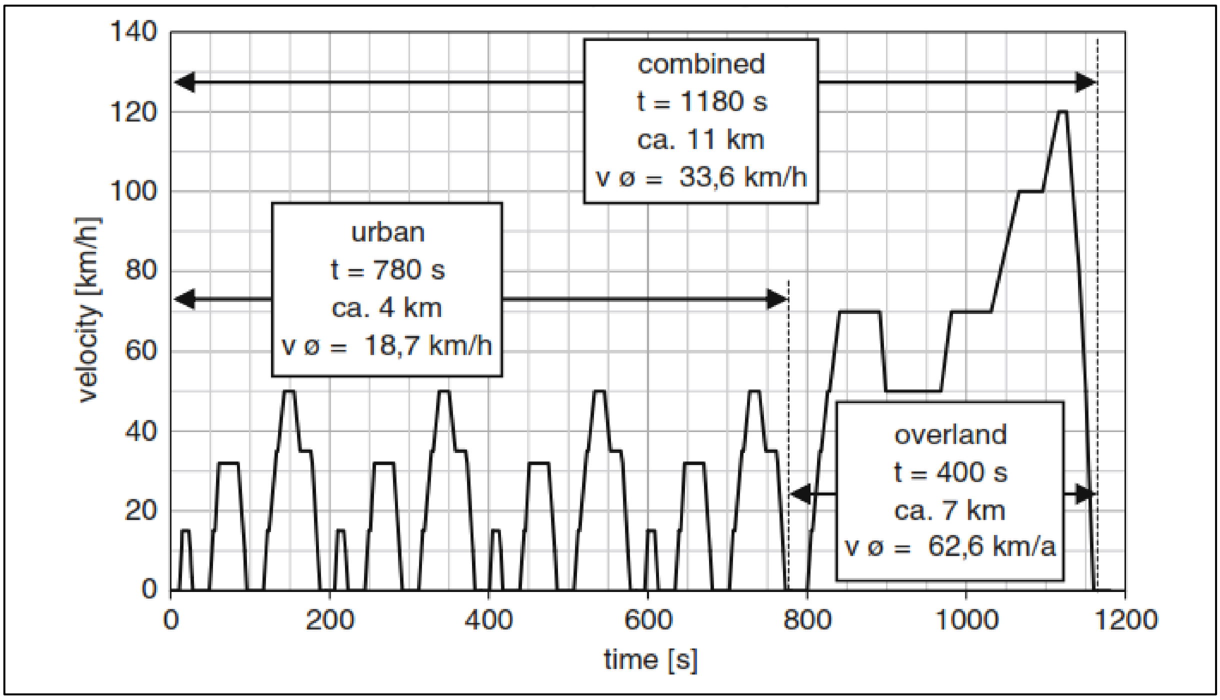
List of Abbreviations

AHSS	Advanced High Strength Steel
ASSAB	Associated Swedish Steel Aktiebolag
BH	Bake Hardenable
BIW	Body In White
CAGR	Compound Annual Growth Rate
CO_2	Carbon Dioxide
CP	Complex Phase
DP	Dual Phase
DPI	Disposable Personal Income
EU	European Union
EV	Electric Vehicle
GDP	Gross Domestic Product
GM	General Motors
HSIF	High Strength Interstitial Free
HSLA	High Strength Low Alloy
HSS	High Strength Steel
ICE	Internal Combustion Engine
MPa	Mega Pascal
MQB	Modularer Querbaukasten
MS	Martensitic Steel
OEM	Original Equipment Manufacturer
PATAC	Pan Asia Technical Automotive Center
PHEV	Plug In Hybrid Electric Vehicle
PHS	Press Hardened Steel
PPP	Purchasing Power Parity
PSA	Peugeot Société Anonyme
SAIC	Shanghai Automotive Industry Corporation

SVW	Shanghai Volkswagen
SWOT	Strengths – Weaknesses – Opportunities – Threats
R_m	Ultimate tensile Strength
TRIP	Transformation Induced Plasticity
UHSS	Ultra High Strength Steel
USD	United States Dollar

Appendix A: New European Driving Cycle NEDC

The driving cycle builds the basis for measuring the fuel consumption. In Europe the New European Driving Cycle (NEDC) is since 1996 mandatory part of the homologation of new passenger cars. 780 seconds of the test are an urban cycle and 400 seconds are extra urban cycle The average speed is 33,6 kilometres per hour and the cars are accelerated to a maximum speed of 120 kilometres per hour. The driving distance is 11 kilometres. How representative the NEDC and if its showing the "real" fuel consumption of a passenger car is always part of discussion, but at least it provides a standardized method which makes the fuel consumption comparable among the different cars models.[269]



Time and Speed Pattern of the New European Driving Cycle NEDC[270]

[269] Cf. Koffler/Rhode-Brandenburger (2009), p. 129
[270] Koffler/Rhode-Brandenburger (2009), p. 130

Appendix B: European Emission Standards Penalty Payment

The (2009), Article 9, Paragraph 1,2:[271]

1. In respect of each calendar year from 2012 onwards for which a manufacturer's average specific emissions of CO2 exceed its specific emissions target in that year, the commission shall impose an excess emissions premium on the manufacturer or, in the case of a pool, the pool manager.

2. The excess emissions premium under paragraph 1 shall be calculated using the following formulae:

(a) From 2012 until 2018:

(i) Where the manufacturer's average specific emissions of CO_2 exceed its specific emissions target by more than 3 g CO_2/km: ((Excess emissions – 3 g CO_2/km) x 95 €/g CO_2/km +1 g CO_2/km x 25 €/g CO_2/km + 1 g CO_2/km x 15 €/g CO_2/km + 1 g CO_2/km x 5 €/g CO_2/km) x number of new passenger cars.

(ii) Where the manufacturer's average specific emissions of CO2 exceed its specific emissions target by more than
2 g CO2/km but no more than 3 g CO2/km:

((Excess emissions – 2 g CO_2/km) x 25 €/g CO_2/km + 1 g CO_2/km x 15 €/g CO_2/km + 1 g CO_2/km x 5 €/g CO_2/km) x number of new passenger cars.

(iii) Where the manufacturer's average specific emissions of CO2 exceed its specific emissions target by more than 1
but no more than 2 g CO2/km:

((Excess emissions – 1 g CO_2/km) x 15 €/g CO_2/km + 1 g CO_2/km x 5 €/g CO_2/km) x number of new passenger cars.

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[271] The (2009), REGULATION (EC) No 443/2009 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 23 April 2009 setting emission performance standards for new passenger cars as part of the Community's integrated approach to reduce CO2 emissions from light-duty vehicles

(iv) Where the manufacturer's average specific emissions of CO2 exceed its specific emissions target by more than 1
but no more than 1 g CO2/km:

(Excess emissions x 5 €/g CO_2/km) x number of new passenger cars.

(b) From 2019:

(Excess emissions x 95 €/g CO_2/km) × number of new passenger cars.

Appendix C: Calculation of Press Hardening Tool Steel Potential for Europe

Year	Cycle time [s][272]	Working Hours per Day [h]	Working Days per Year [days]	Shots per Year and Line [#]	Die Life [#][273]	Die Quantity per Line [# sets]	% of Each shot Producing 1 Part[274]	% of Each Shot Producing 2 Parts[275]	Average Number of Parts Produced by Each Shot [#]	Annual Productivity per Line [#]	Average Tool Steel Need per Part [tons][276]	Average Tool Steel Need per Die [tons]	Average Tool Steel Need per Line [tons]
2013	19,00	20,00	300,00	1.136.842	650.000	1,75	0,10	0,90	1,90	2.160.000	3,00	5,70	9,97
2014	19,00	20,00	300,00	1.136.842	660.000	1,72	0,10	0,90	1,90	2.160.000	3,00	5,70	9,82
2015	18,50	20,00	300,00	1.167.568	670.000	1,74	0,10	0,90	1,90	2.218.378	3,00	5,70	9,93
2016	18,00	20,00	300,00	1.200.000	680.000	1,76	0,10	0,90	1,90	2.280.000	3,00	5,70	10,06
2017	17,50	20,00	300,00	1.234.286	690.000	1,79	0,10	0,90	1,90	2.345.143	3,00	5,70	10,20
2018	17,00	20,00	300,00	1.270.588	700.000	1,82	0,10	0,90	1,90	2.414.118	3,00	5,70	10,35
2019	16,50	20,00	300,00	1.309.091	710.000	1,84	0,10	0,90	1,90	2.487.273	3,00	5,70	10,51
2020	16,00	20,00	300,00	1.350.000	720.000	1,88	0,10	0,90	1,90	2.565.000	3,00	5,70	10,69
2021	15,50	20,00	300,00	1.393.548	730.000	1,91	0,10	0,90	1,90	2.647.742	3,00	5,70	10,88
2022	15,00	20,00	300,00	1.440.000	740.000	1,95	0,10	0,90	1,90	2.736.000	3,00	5,70	11,09
2023	14,50	20,00	300,00	1.489.655	750.000	1,99	0,10	0,90	1,90	2.830.345	3,00	5,70	11,32
2024	14,00	20,00	300,00	1.542.857	760.000	2,03	0,10	0,90	1,90	2.931.429	3,00	5,70	11,57
2025	13,50	20,00	300,00	1.600.000	770.000	2,08	0,10	0,90	1,90	3.040.000	3,00	5,70	11,84
2026	13,40	20,00	300,00	1.611.940	780.000	2,07	0,10	0,90	1,90	3.062.687	3,00	5,70	11,78
2027	13,30	20,00	300,00	1.624.060	780.000	2,08	0,10	0,90	1,90	3.085.714	3,00	5,70	11,87
2028	13,20	20,00	300,00	1.636.364	780.000	2,10	0,10	0,90	1,90	3.109.091	3,00	5,70	11,96

Table C-1: Calculation of Average Tool Steel Need per Line

[272] Jerker Andersson, Business Developer Hot Work Tool Steel, Uddeholms AB
[273] ibidem
[274] Eason Fan, Business Development Manager (Automotive), ASSAB Tooling Technology Co Ltd
[275] ibidem
[276] Calculated out of Table 7-2 followed by a Discussion with Mr Jerker Andersson, Business Developer Hot Work Tool Steel, Uddeholms AB

Calculation Scheme for Table C-1:

(Cycle time) * (Working Hours per Day) * (Working Days per Year) = Shots per Year and Line

(Shots per Year and Line) / (Die Life) = Die Quantity per Line

(% of Each Shot Producing 1 Part) * 1 + (% of Each Shot Producing 2 Parts) * 2 = Average Number of Part Produced by Each Shot

(Stamping Shots per Year and Line) * (Average Number of Part Produced by Each Shot) = Annual Productivity per Line

(Average Number of Part Produced by Each Shot) * (Annual Productivity per Line) = Average Tool Steel Need per Die

(Die Quantity per Line) * (Average Tool Steel Need per Die) = Average Tool Steel Need per Line

This Calculation Scheme is also valid for Table D-1 in Appendix D

PV Production European Manufacturer [# cars][277]	PV Production European Manufacturer [# cars] LOW[278]	PV Production European Manufacturer [# cars] HIGH[279]	average hot stamping parts per car [#][280]	average hot stamping parts per car [#] LOW[281]	average hot stamping parts per car [#] HIGH[282]	quantity of hot stamping parts [#]	quantity of hot stamping parts [#]	quantity of hot stamping parts [#]	Line need to meet pot. Prod. [#]	Line need to meet pot. Prod. [#] LOW	Line need to meet pot. Prod. [#] HIGH	Annual tool steel potential European Manufacturer [tons]	Annual tool steel potential European Manufactur er [tons] LOW	Annual tool steel potential European Manufactur er [tons] HIGH
10.620.151	10.620.151	10.620.151	17	17	17	180.542.567	180.542.567	180.542.567	84	84	84	833	833	833
10.732.245	10.624.923	10.839.567	18	18	18	193.180.410	191.248.606	195.112.214	89	89	90	878	869	887
11.456.951	11.342.381	11.571.521	19	18	20	217.682.069	204.162.867	231.430.410	98	92	104	975	914	1.036
11.914.803	11.795.655	12.033.951	20	19	21	238.296.060	224.117.444	252.712.972	105	98	111	1.051	989	1.115
12.495.621	12.370.665	12.620.577	21	20	22	262.408.041	247.413.296	277.652.699	112	106	118	1.141	1.076	1.207
12.677.183	12.550.411	12.803.955	22	20	24	278.898.026	251.008.223	307.294.916	116	104	127	1.195	1.076	1.317
12.884.869	12.756.020	13.013.718	23	21	25	296.351.987	267.876.427	325.342.942	119	108	131	1.252	1.132	1.375
13.314.042	13.180.902	13.447.182	24	22	26	319.537.008	289.979.835	349.626.743	125	113	136	1.331	1.208	1.457
13.510.823	13.375.715	13.645.931	25	22	28	337.770.577	294.265.727	382.086.077	128	111	144	1.388	1.209	1.570
13.707.611	13.570.535	13.844.687	26	23	29	356.397.888	312.122.305	401.495.929	130	114	147	1.445	1.265	1.628
13.904.399	13.765.355	14.043.443	27	24	30	375.418.776	330.368.522	421.303.293	133	117	149	1.502	1.321	1.685
13.987.107	13.847.236	14.126.978	28	24	32	391.638.999	332.333.665	452.063.301	134	113	154	1.546	1.312	1.784
14.069.815	13.929.117	14.210.513	29	25	33	408.024.638	348.227.924	468.946.937	134	115	154	1.590	1.357	1.827
14.152.523	14.010.998	14.294.048	29	25	33	410.423.170	350.274.947	471.703.595	134	114	154	1.579	1.347	1.814
14.235.231	14.092.879	14.377.583	29	24	34	412.821.702	338.229.091	488.837.836	134	110	158	1.588	1.301	1.880
14.317.939	14.174.760	14.461.118	29	23	33	415.220.234	326.019.473	477.216.910	134	105	153	1.597	1.254	1.835

Table C-2: Calculation of Annual Tool Steel Potential for European Manufacturers

[277] Data from LMC Automotive, Uddeholm internal, accessed April 10th 2013
[278] Estimations according to a Discussion with Mr Pär Emanuelsson, Sales Director Uddeholms AB
[279] Estimations according to a Discussion with Mr Pär Emanuelsson, Sales Director Uddeholms AB
[280] Estimations according to the results of chapter 7 followed by a Discussion with Mr Nader Asnafi, Vice President – Research and Development, Uddeholms AB
[281] Estimations according to the results of chapter 7 followed by a Discussion with Mr Nader Asnafi, Vice President – Research and Development, Uddeholms AB
[282] Estimations according to the results of chapter 7 followed by a Discussion with Mr Nader Asnafi, Vice President – Research and Development, Uddeholms AB

Calculation Scheme for Table C-2:

(PV Production European Manufacturers) * (Average Hot Stamping Parts per Car) = Quantity of Hot Stamping Parts

(Annual Productivity per Line) / (Quantity of Hot Stamping Parts) = Line Need to meet potential Production

(Average Tool Steel Need per Line) * (Line Need to meet potential Production) = Annual Tool Steel European Manufacturer

The same way of calculation is used for LOW and HIGH development.

Annual Productivity per Line and Average Tool Steel Need per Line out of Table C-1

This Calculation Scheme is also valid for Table C-3 to C-7 and Table D-3 to D-7 in Appendix D

PV Production North American Manufacturer [# cars][283]	PV Production North American Manufacturer [# cars] LOW[284]	PV Production North American Manufacturer [# cars] HIGH[285]	average hot stamping parts per car [#][286]	average hot stamping parts per car [#] LOW[287]	average hot stamping parts per car [#] HIGH[288]	quantity of hot stamping parts [#]	quantity of hot stamping parts [#]	quantity of hot stamping parts [#]	Line need to meet pot. Prod [#]	Line need to meet pot. Prod [#] LOW	Line need to meet pot. Prod [#] HIGH	Annual tool steel potential North American Manufacturer [tons]	Annual tool steel potential North American Manufacturer [tons] LOW	Annual tool steel potential North American Manufacturer [tons] HIGH
1.933.689	1.933.689	1.933.689	15	15	15	29.005.335	29.005.335	29.005.335	13	13	13	134	134	134
1.834.547	1.779.511	1.889.583	16	16	16	29.352.752	28.472.169	30.233.335	14	13	14	133	129	137
1.962.180	1.864.071	2.060.289	17	16	18	33.357.060	29.825.136	37.085.202	15	13	17	149	134	166
1.955.990	1.858.191	2.053.790	18	17	19	35.207.820	31.589.239	39.022.001	15	14	17	155	139	172
2.148.108	2.040.703	2.255.513	19	18	20	40.814.052	36.732.647	45.110.268	17	16	19	177	160	196
2.350.433	2.232.911	2.467.955	20	18	22	47.008.660	40.192.404	54.295.002	19	17	22	201	172	233
2.384.006	2.264.806	2.503.206	21	19	23	50.064.126	43.031.308	57.573.745	20	17	23	212	182	243
2.416.078	2.295.274	2.536.882	22	20	24	53.153.716	45.905.482	60.885.166	21	18	24	221	191	254
2.463.404	2.340.234	2.586.574	23	20	26	56.658.290	46.804.675	67.250.927	21	18	25	233	192	276
2.499.284	2.374.320	2.624.248	24	21	27	59.982.814	49.860.714	70.854.699	22	18	26	243	202	287
2.535.164	2.408.406	2.661.922	25	22	28	63.379.098	52.984.926	74.533.820	22	19	26	254	212	298
2.550.244	2.422.732	2.677.756	26	22	30	66.306.342	53.300.098	80.332.684	23	18	27	262	210	317
2.565.324	2.437.058	2.693.590	27	23	31	69.263.746	56.052.328	83.501.294	23	18	27	270	218	325
2.580.404	2.451.384	2.709.424	28	24	32	72.251.310	58.833.210	86.701.572	24	19	28	278	226	333
2.595.484	2.465.710	2.725.258	28	23	33	72.673.550	56.711.324	89.933.518	24	18	29	280	218	346
2.610.564	2.480.036	2.741.092	29	23	33	75.706.354	57.040.822	90.456.040	24	18	29	291	219	348

Table C-3: Calculation of Annual Tool Steel Potential for North American Manufacturers

[283] Data from LMC Automotive, Uddeholm internal, accessed April 10th 2013
[284] Estimations according to a Discussion with Mr Pär Emanuelsson, Sales Director Uddeholms AB
[285] Estimations according to a Discussion with Mr Pär Emanuelsson, Sales Director Uddeholms AB
[286] Estimations according to the results of chapter 7 followed by a Discussion with Mr Nader Asnafi, Vice President – Research and Development, Uddeholms AB
[287] Estimations according to the results of chapter 7 followed by a Discussion with Mr Nader Asnafi, Vice President – Research and Development, Uddeholms AB
[288] Estimations according to the results of chapter 7 followed by a Discussion with Mr Nader Asnafi, Vice President – Research and Development, Uddeholms AB

PV Production Chinese Manufacturer (mainly VOLVO) [# cars][289]	PV Production Chinese Manufacturer [# cars] LOW[290]	PV Production Chinese Manufacturer [# cars] HIGH[291]	average hot stamping parts per car [#][292]	average hot stamping parts per car [#] LOW[293]	average hot stamping parts per car [#] HIGH[294]	quantity of hot stamping parts [#]	quantity of hot stamping parts [#]	quantity of hot stamping parts [#]	Line need to meet potential production [#]	Line need to meet potential production [#] LOW	Line need to meet potential production [#] HIGH	Annual tool steel potential Chinese Manufacturer (mainly VOLVO) [tons]	Annual tool steel potential Chinese Manufacturer [tons] LOW	Annual tool steel potential Chinese Manufacturer [tons] HIGH
375.543	375.543	375.543	17	17	17	6.384.231	6.384.231	6.384.231	3	3	3	29	29	29
345.343	334.983	355.703	18	18	18	6.216.174	6.029.689	6.402.659	3	3	3	28	27	29
420.501	399.476	441.526	19	18	20	7.989.519	7.190.567	8.830.521	4	3	4	36	32	40
462.771	439.632	485.910	20	19	21	9.255.420	8.353.017	10.204.101	4	4	4	41	37	45
482.881	458.737	507.025	21	20	22	10.140.501	9.174.739	11.154.551	4	4	5	44	40	48
472.213	448.602	495.824	22	20	24	10.388.686	8.972.047	11.899.768	4	4	5	45	38	51
498.772	473.833	523.711	23	21	25	11.471.756	9.950.501	13.092.765	5	4	5	48	42	55
515.100	489.345	540.855	24	22	26	12.362.400	10.765.590	14.062.230	5	4	5	52	45	59
530.579	504.050	557.108	25	22	28	13.264.483	11.089.108	15.599.032	5	4	6	55	46	64
538.307	511.392	565.223	26	23	29	13.995.990	11.762.015	16.391.458	5	4	6	57	48	66
546.035	518.734	573.337	27	24	30	14.742.953	12.449.605	17.200.112	5	4	6	59	50	69
549.283	521.819	576.747	28	24	32	15.379.933	12.523.659	18.455.919	5	4	6	61	49	73
552.531	524.905	580.158	29	25	33	16.023.408	13.122.619	19.145.210	5	4	6	62	51	75
555.779	527.990	583.568	29	25	33	16.117.600	13.199.759	19.257.753	5	4	6	62	51	74
559.027	531.076	586.979	29	24	34	16.211.792	12.745.823	19.957.275	5	4	6	62	49	77
562.275	534.162	590.389	29	23	33	16.305.984	12.285.715	19.482.839	5	4	6	63	47	75

Table C-4: Calculation of Annual Tool Steel Potential for Chinese Manufacturers

[289] Data from LMC Automotive, Uddeholm internal, accessed April 10th 2013
[290] Estimations according to a Discussion with Mr Pär Emanuelsson, Sales Director Uddeholms AB
[291] Estimations according to a Discussion with Mr Pär Emanuelsson, Sales Director Uddeholms AB
[292] Estimations according to the results of chapter 7 followed by a Discussion with Mr Nader Asnafi, Vice President – Research and Development, Uddeholms AB
[293] Estimations according to the results of chapter 7 followed by a Discussion with Mr Nader Asnafi, Vice President – Research and Development, Uddeholms AB
[294] Estimations according to the results of chapter 7 followed by a Discussion with Mr Nader Asnafi, Vice President – Research and Development, Uddeholms AB

PV Production Japanese Manufacturer [# cars][295]	PV Production Japanese Manufacturer [# cars] LOW[296]	PV Production Japanese Manufacturer [# cars] HIGH[297]	average hot stamping parts per car [#][298]	average hot stamping parts per car [#] LOW[299]	average hot stamping parts per car [#] HIGH[300]	quantity of hot stamping parts [#]	quantity of hot stamping parts [#]	quantity of hot stamping parts [#]	Line need to meet potential production [#]	Line need to meet potential production [#] LOW	Line need to meet potential production [#] HIGH	Annual tool steel potential Japanese Manufacturer [tons]	Annual tool steel potential Japanese Manufacturer [tons] LOW	Annual tool steel potential Japanese Manufacturer [tons] HIGH
793.543	793.543	793.543	8	8	8	6.348.344	6.348.344	6.348.344	3	3	3	29	29	29
833.424	808.421	858.427	8	8	8	6.667.392	6.467.370	6.867.414	3	3	3	30	29	31
825.307	784.042	866.572	9	8	10	7.427.763	6.272.333	8.665.724	3	3	4	33	28	39
884.784	840.545	929.023	9	8	10	7.963.056	6.724.358	9.290.232	3	3	4	35	30	41
964.305	916.090	1.012.520	10	9	11	9.643.050	8.244.808	11.137.723	4	4	5	42	36	48
1.032.905	981.260	1.084.550	11	9	13	11.361.955	8.831.338	14.099.153	5	4	6	49	38	60
1.034.783	983.044	1.086.522	12	10	14	12.417.396	9.830.439	15.211.310	5	4	6	52	42	64
1.050.853	998.310	1.103.396	13	11	15	13.661.089	10.981.414	16.550.935	5	4	6	57	46	69
1.023.260	972.097	1.074.423	14	11	17	14.325.641	10.693.068	18.265.193	5	4	7	59	44	75
1.038.164	986.256	1.090.072	15	12	18	15.572.461	11.835.071	19.621.301	6	4	7	63	48	80
1.053.068	1.000.415	1.105.721	16	13	19	16.849.090	13.005.391	21.008.708	6	5	7	67	52	84
1.059.332	1.006.365	1.112.299	17	13	21	18.008.646	13.082.751	23.358.273	6	4	8	71	52	92
1.065.596	1.012.316	1.118.876	19	15	23	20.246.326	15.184.744	25.734.146	7	5	8	79	59	100
1.071.860	1.018.267	1.125.453	19	15	23	20.365.342	15.274.006	25.885.421	7	5	8	78	59	100
1.078.124	1.024.218	1.132.030	20	15	25	21.562.482	15.363.268	28.300.757	7	5	9	83	59	109
1.084.388	1.030.169	1.138.607	20	14	24	21.687.762	14.422.362	27.326.580	7	5	9	83	55	105

Table C-5: Calculation of Annual Tool Steel Potential for Japanese Manufacturers

[295] Data from LMC Automotive, Uddeholm internal, accessed April 10th 2013
[296] Estimations according to a Discussion with Mr Pär Emanuelsson, Sales Director Uddeholms AB
[297] Estimations according to a Discussion with Mr Pär Emanuelsson, Sales Director Uddeholms AB
[298] Estimations according to the results of chapter 7 followed by a Discussion with Mr Nader Asnafi, Vice President – Research and Development, Uddeholms AB
[299] Estimations according to the results of chapter 7 followed by a Discussion with Mr Nader Asnafi, Vice President – Research and Development, Uddeholms AB
[300] Estimations according to the results of chapter 7 followed by a Discussion with Mr Nader Asnafi, Vice President – Research and Development, Uddeholms AB

PV Production Korean Manufacturer [# cars][301]	PV Production Korean Manufacturer [# cars] LOW[302]	PV Production Korean Manufacturer [# cars] HIGH[303]	average hot stamping parts per car [#][304]	average hot stamping parts per car [#] LOW[305]	average hot stamping parts per car [#] HIGH[306]	quantity of hot stamping parts [#]	quantity of hot stamping parts [#]	quantity of hot stamping parts [#]	Line need to meet potential production [#]	Line need to meet potential production [#] LOW	Line need to meet potential production [#] HIGH	Annual tool steel potential Korean Manufacturer [tons]	Annual tool steel potential Korean Manufacturer [tons] LOW	Annual tool steel potential Korean Manufacturer [tons] HIGH
622.128	622.128	622.128	10	10	10	6.221.280	6.221.280	6.221.280	3	3	3	29	29	29
650.745	631.223	670.267	11	11	11	7.158.195	6.943.449	7.372.941	3	3	3	33	32	34
654.094	621.389	686.799	11	10	12	7.195.034	6.213.893	8.241.584	3	3	4	32	28	37
674.467	640.744	708.190	12	11	13	8.093.604	7.048.180	9.206.475	4	3	4	36	31	41
718.224	682.313	754.135	12	11	13	8.618.688	7.505.441	9.803.758	4	3	4	37	33	43
764.586	726.357	802.815	13	11	15	9.939.618	7.989.924	12.042.230	4	3	5	43	34	52
803.923	763.727	844.119	14	12	16	11.254.922	9.164.722	13.505.906	5	4	5	48	39	57
789.921	750.425	829.417	15	13	17	11.848.815	9.755.524	14.100.090	5	4	5	49	41	59
833.767	792.079	875.456	16	13	19	13.340.280	10.297.028	16.633.661	5	4	6	55	42	68
845.911	803.616	888.207	17	14	20	14.380.495	11.250.623	17.764.141	5	4	6	58	46	72
858.055	815.153	900.958	18	15	21	15.444.999	12.227.291	18.920.123	5	4	7	62	49	76
863.159	820.002	906.317	20	16	24	17.263.190	13.120.024	21.751.619	6	4	7	68	52	86
868.263	824.850	911.677	20	16	24	17.365.270	13.197.605	21.880.240	6	4	7	68	51	85
873.367	829.699	917.036	21	17	25	18.340.717	14.104.885	22.925.896	6	5	7	71	54	88
878.471	834.548	922.395	21	16	26	18.447.901	13.352.767	23.982.272	6	4	8	71	51	92
883.575	839.397	927.754	21	15	25	18.555.085	12.590.951	23.193.856	6	4	7	71	48	89

Table C-6: Calculation of Annual Tool Steel Potential for Korean Manufacturers

[301] Data from LMC Automotive, Uddeholm internal, accessed April 10th 2013
[302] Estimations according to a Discussion with Mr Pär Emanuelsson, Sales Director Uddeholms AB
[303] Estimations according to a Discussion with Mr Pär Emanuelsson, Sales Director Uddeholms AB
[304] Estimations according to the results of chapter 7 followed by a Discussion with Mr Nader Asnafi, Vice President – Research and Development, Uddeholms AB
[305] Estimations according to the results of chapter 7 followed by a Discussion with Mr Nader Asnafi, Vice President – Research and Development, Uddeholms AB
[306] Estimations according to the results of chapter 7 followed by a Discussion with Mr Nader Asnafi, Vice President – Research and Development, Uddeholms AB

PV Production Other Manufacturer [# cars][307]	PV Production Other Manufacturer [# cars] LOW[308]	PV Production Other Manufacturer [# cars] HIGH[309]	average hot stamping parts per car [#][310]	average hot stamping parts per car [#] LOW[311]	average hot stamping parts per car [#] HIGH[312]	quantity of hot stamping parts [#]	quantity of hot stamping parts [#]	quantity of hot stamping parts [#]	Line need to meet potential production [#]	Line need to meet potential production [#] LOW	Line need to meet potential production [#] HIGH	Annual tool steel potential Other Manufacturers [tons]	Annual tool steel potential Other Manufacturer [tons] LOW	Annual tool steel potential Other Manufacturer [tons] HIGH
440.593	440.593	440.593	2	2	2	881.186	881.186	881.186	0	0	0	4	4	4
455.941	442.263	469.619	3	3	3	1.367.823	1.326.788	1.408.858	1	1	1	6	6	6
438.336	416.419	460.253	3	2	4	1.315.008	832.838	1.841.011	1	0	1	6	4	8
465.378	442.109	488.647	4	3	5	1.861.512	1.326.327	2.443.235	1	1	1	8	6	11
505.953	480.655	531.251	4	3	5	2.023.812	1.441.966	2.656.253	1	1	1	9	6	12
560.115	532.109	588.121	5	3	7	2.800.575	1.596.328	4.116.845	1	1	2	12	7	18
565.821	537.530	594.112	6	4	8	3.394.926	2.150.120	4.752.896	1	1	2	14	9	20
587.267	557.904	616.630	6	4	8	3.523.602	2.231.615	4.933.043	1	1	2	15	9	21
587.427	558.056	616.798	7	4	10	4.111.990	2.232.223	6.167.984	2	1	2	17	9	25
595.983	566.184	625.782	8	5	11	4.767.865	2.830.920	6.883.605	2	1	3	19	11	28
604.539	574.312	634.766	9	6	12	5.440.852	3.445.873	7.617.193	2	1	3	22	14	30
608.135	577.728	638.542	10	6	14	6.081.351	3.466.370	8.939.586	2	1	3	24	14	35
611.731	581.145	642.318	11	7	15	6.729.042	4.068.012	9.634.765	2	1	3	26	16	38
615.327	584.561	646.093	12	8	16	7.383.925	4.676.486	10.337.495	2	2	3	28	18	40
618.923	587.977	649.869	13	8	18	8.046.000	4.703.815	11.697.646	3	2	4	31	18	45
622.519	591.393	653.645	14	8	18	8.715.267	4.731.145	11.765.611	3	2	4	34	18	45

Table C-7: Calculation of Annual Tool Steel Potential for Other Manufacturers

[307] Data from LMC Automotive, Uddeholm internal, accessed April 10th 2013
[308] Estimations according to a Discussion with Mr Pär Emanuelsson, Sales Director Uddeholms AB
[309] Estimations according to a Discussion with Mr Pär Emanuelsson, Sales Director Uddeholms AB
[310] Estimations according to the results of chapter 7 followed by a Discussion with Mr Nader Asnafi, Vice President – Research and Development, Uddeholms AB
[311] Estimations according to the results of chapter 7 followed by a Discussion with Mr Nader Asnafi, Vice President – Research and Development, Uddeholms AB
[312] Estimations according to the results of chapter 7 followed by a Discussion with Mr Nader Asnafi, Vice President – Research and Development, Uddeholms AB

Total line need to meet potential production [#]	Total line need to meet potential production [#] LOW	Total line need to meet potential production [#] HIGH	Total die potential of die sets [# sets]	Total tool steel potential [tons]	Total tool steel potential [tons] LOW	Total tool steel potential [tons] HIGH
106	106	106	186	1.059	1.059	1.059
113	111	115	195	1.109	1.093	1.125
124	115	133	216	1.231	1.140	1.326
132	122	142	233	1.327	1.232	1.424
142	132	152	254	1.451	1.350	1.554
149	132	167	271	1.545	1.365	1.730
155	138	173	285	1.627	1.445	1.815
161	144	179	303	1.725	1.540	1.917
166	142	191	317	1.806	1.543	2.079
170	146	195	331	1.886	1.620	2.161
174	150	198	345	1.965	1.698	2.242
176	146	206	356	2.032	1.689	2.388
177	148	207	367	2.095	1.753	2.450
178	149	208	368	2.096	1.755	2.449
178	143	215	371	2.114	1.697	2.549
179	137	209	375	2.139	1.643	2.498

Table C-8: Calculation of Total Line Need and Total Tool Steel Potential

Appendix D: Calculation of Press Hardening Tool Steel for China

Year	Cycle time [s][313]	Working Hours per Day [h]	Working Days per Year [days]	Shots per Year and Line [#]	Die Life [#][314]	Die Quantity per Line [# sets]	% of Each shot Producing 1 Part[315]	% of Each Shot Producing 2 Parts[316]	Average Number of Parts Produced by Each Shot [#]	Annual Productivity per Line [#]	Average Tool Steel Need per Part [tons][317]	Average Tool Steel Need per Die [tons]	Average Tool Steel Need per Line [tons]
2013	22,00	20,00	300,00	981.818	380.000	2,58	0,10	0,90	1,90	1.865.455	3,00	5,70	14,73
2014	22,00	20,00	300,00	981.818	400.000	2,45	0,10	0,90	1,90	1.865.455	3,00	5,70	13,99
2015	22,00	20,00	300,00	981.818	410.000	2,39	0,10	0,90	1,90	1.865.455	3,00	5,70	13,65
2016	22,00	20,00	300,00	981.818	420.000	2,34	0,10	0,90	1,90	1.865.455	3,00	5,70	13,32
2017	21,00	20,00	300,00	1.028.571	430.000	2,39	0,10	0,90	1,90	1.954.286	3,00	5,70	13,63
2018	21,00	20,00	300,00	1.028.571	440.000	2,34	0,10	0,90	1,90	1.954.286	3,00	5,70	13,32
2019	21,00	20,00	300,00	1.028.571	450.000	2,29	0,10	0,90	1,90	1.954.286	3,00	5,70	13,03
2020	21,00	20,00	300,00	1.028.571	460.000	2,24	0,10	0,90	1,90	1.954.286	3,00	5,70	12,75
2021	20,00	20,00	300,00	1.080.000	470.000	2,30	0,10	0,90	1,90	2.052.000	3,00	5,70	13,10
2022	20,00	20,00	300,00	1.080.000	480.000	2,25	0,10	0,90	1,90	2.052.000	3,00	5,70	12,83
2023	20,00	20,00	300,00	1.080.000	490.000	2,20	0,10	0,90	1,90	2.052.000	3,00	5,70	12,56
2024	20,00	20,00	300,00	1.080.000	500.000	2,16	0,10	0,90	1,90	2.052.000	3,00	5,70	12,31
2025	20,00	20,00	300,00	1.080.000	510.000	2,12	0,10	0,90	1,90	2.052.000	3,00	5,70	12,07
2026	19,50	20,00	300,00	1.107.692	520.000	2,13	0,10	0,90	1,90	2.104.615	3,00	5,70	12,14
2027	19,00	20,00	300,00	1.136.842	530.000	2,14	0,10	0,90	1,90	2.160.000	3,00	5,70	12,23
2028	18,50	20,00	300,00	1.167.568	540.000	2,16	0,10	0,90	1,90	2.218.378	3,00	5,70	12,32

Table D-1: Calculation of Average Tool Steel Need per Line

313 Jerker Andersson, Business Developer Hot Work Tool Steel, Uddeholms AB
314 ibidem
315 Eason Fan, Business Development Manager (Automotive), ASSAB Tooling Technology Co Ltd
316 ibidem
317 Calculated out of Table 7-2 followed by a Discussion with Mr Jerker Andersson, Business Developer Hot Work Tool Steel, Uddeholms AB

PV Production European Manufacturer [# cars][318]	PV Production European Manufacturer [# cars] LOW[319]	PV Production European Manufacturer [# cars] HIGH[320]	average hot stamping parts per car [#][321]	average hot stamping parts per car [#] LOW[322]	average hot stamping parts per car [#] HIGH[323]	quantity of hot stamping parts [#]	quantity of hot stamping parts [#]	quantity of hot stamping parts [#]	Line need to meet potential production [#]	Line need to meet potential production [#] LOW	Line need to meet potential production [#] HIGH	Annual tool steel potential European Manufacturer [tons]	Annual tool steel potential European Manufacturer [tons] LOW	Annual tool steel potential European Manufacturer [tons] HIGH
4.560.546	4.560.546	4.560.546	17	17	17	77.529.282	77.529.282	77.529.282	42	42	42	612	612	612
5.328.691	5.275.404	5.381.978	18	18	18	95.916.438	94.957.274	96.875.602	51	51	52	719	712	727
5.952.679	5.893.152	6.012.206	19	18	20	113.100.901	106.076.740	120.244.116	61	57	64	828	776	880
6.504.715	6.439.668	6.569.762	20	19	21	130.094.300	122.353.689	137.965.005	70	66	74	929	874	985
6.879.083	6.810.292	6.947.874	21	20	22	144.460.743	136.205.843	152.853.224	74	70	78	1.008	950	1.066
7.166.924	7.095.255	7.238.593	22	20	24	157.672.328	141.905.095	173.726.238	81	73	89	1.075	968	1.184
7.341.928	7.268.509	7.415.347	23	21	25	168.864.344	152.638.683	185.383.682	86	78	95	1.126	1.018	1.236
7.519.169	7.443.977	7.594.361	24	22	26	180.460.056	163.767.501	197.453.378	92	84	101	1.177	1.068	1.288
7.717.022	7.639.851	7.794.192	25	22	28	192.925.539	168.076.730	218.237.370	94	82	106	1.231	1.073	1.393
7.891.989	7.813.069	7.970.908	26	23	29	205.191.703	179.700.580	231.156.345	100	88	113	1.282	1.123	1.445
8.066.956	7.986.286	8.147.625	27	24	30	217.807.800	191.670.864	244.428.754	106	93	119	1.334	1.173	1.497
8.134.564	8.053.218	8.215.909	28	24	32	227.767.780	193.277.230	262.909.095	111	94	128	1.367	1.160	1.577
8.202.172	8.120.150	8.284.193	29	25	33	237.862.976	203.003.746	273.378.379	116	99	133	1.399	1.194	1.608
8.269.780	8.187.082	8.352.477	29	25	33	239.823.608	204.677.044	275.631.753	114	97	131	1.384	1.181	1.590
8.337.388	8.254.014	8.420.761	29	24	34	241.784.240	198.096.329	286.305.889	112	92	133	1.369	1.121	1.621
8.404.996	8.320.946	8.489.046	29	23	33	243.744.872	191.381.749	280.138.502	110	86	126	1.354	1.063	1.556

Table D-2: Calculation of Annual Tool Steel Potential for European Manufacturers

318 Data from LMC Automotive, Uddeholm internal, accessed April 10th 2013
319 Estimations according to a Discussion with Mr Pär Emanuelsson, Sales Director Uddeholms AB
320 Estimations according to a Discussion with Mr Pär Emanuelsson, Sales Director Uddeholms AB
321 Estimations according to the results of chapter 7 followed by a Discussion with Mr Nader Asnafi, Vice President – Research and Development, Uddeholms AB
322 Estimations according to the results of chapter 7 followed by a Discussion with Mr Nader Asnafi, Vice President – Research and Development, Uddeholms AB
323 Estimations according to the results of chapter 7 followed by a Discussion with Mr Nader Asnafi, Vice President – Research and Development, Uddeholms AB

PV Production North American Manufacturer [# cars][324]	PV Production North American Manufacturer [# cars] LOW[325]	PV Production North American Manufacturer [# cars] HIGH[326]	average hot stamping parts per car [#][327]	average hot stamping parts per car [#] LOW[328]	average hot stamping parts per car [#] HIGH[329]	quantity of hot stamping parts [#]	quantity of hot stamping parts [#]	quantity of hot stamping parts [#]	Line need to meet potential production [#]	Line need to meet potential production [#] LOW	Line need to meet potential production [#] HIGH	Annual tool steel potential North American Manufacturer [tons]	Annual tool steel potential North American Manufacturer [tons] LOW	Annual tool steel potential North American Manufacturer [tons] HIGH
2.072.517	2.072.517	2.072.517	15	15	15	31.087.755	31.087.755	31.087.755	17	17	17	245	245	245
2.318.826	2.249.261	2.388.391	16	16	16	37.101.216	35.988.180	38.214.252	20	19	20	278	270	287
2.625.320	2.494.054	2.756.586	17	16	18	44.630.440	39.904.864	49.618.548	24	21	27	327	292	363
2.870.997	2.727.447	3.014.547	18	17	19	51.677.946	46.366.602	57.276.390	28	25	31	369	331	409
3.003.023	2.852.872	3.153.174	19	18	20	57.057.437	51.351.693	63.063.483	29	26	32	398	358	440
3.123.368	2.967.200	3.279.536	20	18	22	62.467.360	53.409.593	72.149.801	32	27	37	426	364	492
3.215.858	3.055.065	3.376.651	21	19	23	67.533.018	58.046.237	77.662.971	35	30	40	450	387	518
3.273.152	3.109.494	3.436.810	22	20	24	72.009.344	62.189.888	82.483.430	37	32	42	470	406	538
3.353.083	3.185.429	3.520.737	23	20	26	77.120.906	63.708.574	91.539.162	38	31	45	492	407	584
3.429.107	3.257.652	3.600.562	24	21	27	82.298.565	68.410.682	97.215.179	40	33	47	514	428	608
3.505.131	3.329.874	3.680.387	25	22	28	87.628.271	73.257.235	103.050.847	43	36	50	536	449	631
3.534.507	3.357.782	3.711.232	26	22	30	91.897.178	73.871.193	111.336.966	45	36	54	551	443	668
3.563.883	3.385.689	3.742.077	27	23	31	96.224.837	77.870.840	116.004.387	47	38	57	566	458	682
3.593.259	3.413.596	3.772.922	29	25	33	104.204.507	85.339.898	124.506.419	50	41	59	601	492	718
3.622.635	3.441.503	3.803.767	29	24	34	105.056.411	82.596.075	129.328.064	49	38	60	595	468	732
3.652.011	3.469.410	3.834.611	29	23	33	105.908.315	79.796.437	126.542.176	48	36	57	588	443	703

Table D-3: Calculation of Annual Tool Steel Potential for North American Manufacturers

324 Data from LMC Automotive, Uddeholm internal, accessed April 10th 2013
325 Estimations according to a Discussion with Mr Pär Emanuelsson, Sales Director Uddeholms AB
326 Estimations according to a Discussion with Mr Pär Emanuelsson, Sales Director Uddeholms AB
327 Estimations according to the results of chapter 7 followed by a Discussion with Mr Nader Asnafi, Vice President – Research and Development, Uddeholms AB
328 Estimations according to the results of chapter 7 followed by a Discussion with Mr Nader Asnafi, Vice President – Research and Development, Uddeholms AB
329 Estimations according to the results of chapter 7 followed by a Discussion with Mr Nader Asnafi, Vice President – Research and Development, Uddeholms AB

PV Production Chinese Manufacturer[# cars[330]]	PV Production Chinese Manufacturer [# cars] LOW[331]	PV Production Chinese Manufacturer [# cars] HIGH[332]	average hot stamping parts per car [#][333]	average hot stamping parts per car [#] LOW[334]	average hot stamping parts per car [#] HIGH[335]	quantity of hot stamping parts [#]	quantity of hot stamping parts [#]	quantity of hot stamping parts [#]	Line need to meet potential production [#]	Line need to meet potential production [#] LOW	Line need to meet potential production [#] HIGH	Annual tool steel potential Chinese Manufacturer [tons]	Annual tool steel potential Chinese Manufacturer [tons] LOW	Annual tool steel potential Chinese Manufacturer [tons] HIGH
4.682.583	4.682.583	4.682.583	6	6	6	28.095.498	28.095.498	28.095.498	15	15	15	222	222	222
5.648.806	5.479.342	5.818.270	6	6	6	33.892.836	32.876.051	34.909.621	18	18	19	254	247	262
6.384.219	6.065.008	6.703.430	7	6	8	44.689.533	36.390.048	53.627.440	24	20	29	327	266	392
7.058.644	6.705.712	7.411.576	7	6	8	49.410.508	40.234.271	59.292.610	26	22	32	353	287	424
7.520.862	7.144.819	7.896.905	8	7	9	60.166.896	50.013.732	71.072.146	31	26	36	420	349	496
7.773.310	7.384.645	8.161.976	9	7	11	69.959.790	51.692.512	89.781.731	36	26	46	477	352	612
8.003.976	7.603.777	8.404.175	10	8	12	80.039.760	60.830.218	100.850.098	41	31	52	534	406	672
8.143.072	7.735.918	8.550.226	11	9	13	89.573.792	69.623.266	111.152.933	46	36	57	584	454	725
8.333.397	7.916.727	8.750.067	12	9	15	100.000.765	71.250.545	131.251.004	49	35	64	638	455	838
8.522.339	8.096.222	8.948.456	13	10	16	110.790.408	80.962.221	143.175.297	54	39	70	692	506	895
8.711.281	8.275.717	9.146.845	14	11	17	121.957.935	91.032.887	155.496.368	59	44	76	747	557	952
8.784.289	8.345.075	9.223.504	15	11	19	131.764.336	91.795.821	175.246.568	64	45	85	791	551	1.051
8.857.297	8.414.432	9.300.162	16	12	20	141.716.754	100.973.187	186.003.239	69	49	91	834	594	1.094
8.930.305	8.483.790	9.376.820	17	13	21	151.815.187	110.289.268	196.913.227	72	52	94	876	636	1.136
9.003.313	8.553.147	9.453.479	18	13	23	162.059.636	111.190.917	217.430.011	75	51	101	917	629	1.231
9.076.321	8.622.505	9.530.137	19	13	23	172.450.101	112.092.566	219.193.155	78	51	99	958	623	1.218

Table D-4: Calculation of Annual Tool Steel Potential for Chinese Manufacturers

330 Data from LMC Automotive, Uddeholm internal, accessed April 10th 2013
331 Estimations according to a Discussion with Mr Pär Emanuelsson, Sales Director Uddeholms AB
332 Estimations according to a Discussion with Mr Pär Emanuelsson, Sales Director Uddeholms AB
333 Estimations according to the results of chapter 7 followed by a Discussion with Mr Nader Asnafi, Vice President – Research and Development, Uddeholms AB
334 Estimations according to the results of chapter 7 followed by a Discussion with Mr Nader Asnafi, Vice President – Research and Development, Uddeholms AB
335 Estimations according to the results of chapter 7 followed by a Discussion with Mr Nader Asnafi, Vice President – Research and Development, Uddeholms AB

PV Production Japanese Manufacturer [# cars][336]	PV Production Japanese Manufacturer [# cars] LOW[337]	PV Production Japanese Manufacturer [# cars] HIGH[338]	average hot stamping parts per car [#][339]	average hot stamping parts per car [#] LOW[340]	average hot stamping parts per car [#] HIGH[341]	quantity of hot stamping parts [#]	quantity of hot stamping parts [#]	quantity of hot stamping parts [#]	Line need to meet potential productio n [#]	Line need to meet potential producti on [#] LOW	Line need to meet potential productio n [#] HIGH	Annual tool steel potential Japanese Manufactur er [tons]	Annual tool steel potential Japanese Manufactur er [tons] LOW	Annual tool steel potential Japanese Manufactur er [tons] HIGH
1.830.510	1.830.510	1.830.510	8	8	8	14.644.080	14.644.080	14.644.080	8	8	8	116	116	116
1.985.117	1.925.563	2.044.671	8	8	8	15.880.936	15.404.508	16.357.364	9	8	9	119	116	123
2.206.179	2.095.870	2.316.488	9	8	10	19.855.611	16.766.960	23.164.880	11	9	12	145	123	169
2.395.816	2.276.025	2.515.607	9	8	10	21.562.344	18.208.202	25.156.068	12	10	13	154	130	180
2.539.447	2.412.475	2.666.419	10	9	11	25.394.470	21.712.272	29.330.613	13	11	15	177	151	205
2.659.396	2.526.426	2.792.366	11	9	13	29.253.356	22.737.836	36.300.755	15	12	19	199	155	248
2.760.024	2.622.023	2.898.025	12	10	14	33.120.288	26.220.228	40.572.353	17	13	21	221	175	270
2.817.544	2.676.667	2.958.421	13	11	15	36.628.072	29.443.335	44.376.318	19	15	23	239	192	289
2.872.310	2.728.694	3.015.925	14	11	17	40.212.339	30.015.639	51.270.733	20	15	25	257	192	327
2.937.433	2.790.562	3.084.305	15	12	18	44.061.502	33.486.741	55.517.492	21	16	27	275	209	347
3.002.557	2.852.429	3.152.685	16	13	19	48.040.911	37.081.578	59.901.011	23	18	29	294	227	367
3.027.721	2.876.335	3.179.107	17	13	21	51.471.256	37.392.354	66.761.247	25	18	33	309	224	401
3.052.885	2.900.241	3.205.529	19	15	23	58.004.814	43.503.610	73.727.171	28	21	36	341	256	434
3.078.049	2.924.146	3.231.951	19	15	23	58.482.930	43.862.197	74.334.882	28	21	35	337	253	429
3.103.213	2.948.052	3.258.374	20	15	25	62.064.259	44.220.784	81.459.340	29	20	38	351	250	461
3.128.377	2.971.958	3.284.796	21	15	25	65.695.916	44.579.371	82.119.895	30	20	37	365	248	456

Table D-5: Calculation of Annual Tool Steel Potential for Japanese Manufacturers

336 Data from LMC Automotive, Uddeholm internal, accessed April 10th 2013
337 Estimations according to a Discussion with Mr Pär Emanuelsson, Sales Director Uddeholms AB
338 Estimations according to a Discussion with Mr Pär Emanuelsson, Sales Director Uddeholms AB
339 Estimations according to the results of chapter 7 followed by a Discussion with Mr Nader Asnafi, Vice President – Research and Development, Uddeholms AB
340 Estimations according to the results of chapter 7 followed by a Discussion with Mr Nader Asnafi, Vice President – Research and Development, Uddeholms AB
341 Estimations according to the results of chapter 7 followed by a Discussion with Mr Nader Asnafi, Vice President – Research and Development, Uddeholms AB

PV Production Korean Manufacturer [# cars][342]	PV Production Korean Manufacturer [# cars] LOW[343]	PV Production Korean Manufacturer [# cars] HIGH[344]	average hot stamping parts per car [#][345]	average hot stamping parts per car [#] LOW[346]	average hot stamping parts per car [#] HIGH[347]	quantity of hot stamping parts [#]	quantity of hot stamping parts [#]	quantity of hot stamping parts [#]	Line need to meet potential productio n [#]	Line need to meet potential producti on [#] LOW	Line need to meet potential productio n [#] HIGH	Annual tool steel potential Korean Manufactur er [tons]	Annual tool steel potential Korean Manufactur er [tons] LOW	Annual tool steel potential Korean Manufactur er [tons] HIGH
1.449.190	1.449.190	1.449.190	10	10	10	14.491.900	14.491.900	14.491.900	8	8	8	114	114	114
1.637.614	1.588.486	1.686.742	11	11	11	18.013.754	17.473.341	18.554.167	10	9	10	135	131	139
1.778.033	1.689.131	1.866.935	11	10	12	19.558.363	16.891.314	22.403.216	10	9	12	143	124	164
1.909.849	1.814.357	2.005.341	12	11	13	22.918.188	19.957.922	26.069.439	12	11	14	164	143	186
1.995.491	1.895.716	2.095.266	12	11	13	23.945.892	20.852.881	27.238.452	12	11	14	167	145	190
2.058.926	1.955.980	2.161.872	13	11	15	26.766.038	21.515.777	32.428.085	14	11	17	182	147	221
2.119.909	2.013.914	2.225.904	14	12	16	29.678.726	24.166.963	35.614.471	15	12	18	198	161	237
2.134.965	2.028.217	2.241.713	15	13	17	32.024.475	26.366.818	38.109.125	16	13	20	209	172	249
2.181.969	2.072.871	2.291.068	16	13	19	34.911.510	26.947.322	43.530.289	17	13	21	223	172	278
2.231.441	2.119.869	2.343.013	17	14	20	37.934.495	29.678.163	46.860.258	18	14	23	237	185	293
2.280.912	2.166.867	2.394.958	18	15	21	41.056.422	32.503.001	50.294.118	20	16	25	251	199	308
2.300.028	2.185.027	2.415.030	20	16	24	46.000.567	34.960.431	57.960.715	22	17	28	276	210	348
2.319.144	2.203.187	2.435.102	20	16	24	46.382.887	35.250.994	58.442.438	23	17	28	273	207	344
2.338.260	2.221.347	2.455.173	21	17	25	49.103.468	37.762.905	61.379.334	23	18	29	283	218	354
2.357.376	2.239.508	2.475.245	22	17	27	51.862.280	38.071.628	66.831.620	24	18	31	294	215	378
2.376.492	2.257.668	2.495.317	23	17	27	54.659.324	38.380.352	67.373.558	25	17	30	304	213	374

Table D-6: Calculation of Annual Tool Steel Potential for Korean Manufacturers

[342] Data from LMC Automotive, Uddeholm internal, accessed April 10th 2013
[343] Estimations according to a Discussion with Mr Pär Emanuelsson, Sales Director Uddeholms AB
[344] Estimations according to a Discussion with Mr Pär Emanuelsson, Sales Director Uddeholms AB
[345] Estimations according to the results of chapter 7 followed by a Discussion with Mr Nader Asnafi, Vice President – Research and Development, Uddeholms AB
[346] Estimations according to the results of chapter 7 followed by a Discussion with Mr Nader Asnafi, Vice President – Research and Development, Uddeholms AB
[347] Estimations according to the results of chapter 7 followed by a Discussion with Mr Nader Asnafi, Vice President – Research and Development, Uddeholms AB

PV Production Other Manufacturer [# cars][348]	PV Production Other Manufactur er [# cars] LOW[349]	PV Production Other Manufactur er [# cars] HIGH[350]	average hot stamping parts per car [#][351]	average hot stamping parts per car [#] LOW[352]	average hot stamping parts per car [#] HIGH[353]	quantity of hot stamping parts [#]	quantity of hot stamping parts [#]	quantity of hot stamping parts [#]	Line need to meet potential productio n [#]	Line need to meet potential producti on [#] LOW	Line need to meet potential productio n [#] HIGH	Annual tool steel potential Other Manufactur ers [tons]	Annual tool steel potential Other Manufactur er [tons] LOW	Annual tool steel potential Other Manufactur er [tons] HIGH
55.705	55.705	55.705	2	2	2	111.410	111.410	111.410	0	0	0	1	1	1
68.091	66.048	70.134	3	3	3	204.273	198.145	210.401	0	0	0	2	1	2
125.657	119.374	131.940	3	2	4	376.971	238.748	527.759	0	0	0	3	2	4
156.166	148.358	163.974	4	3	5	624.664	445.073	819.872	0	0	0	4	3	6
176.705	167.870	185.540	4	3	5	706.820	503.609	927.701	0	0	0	5	4	6
186.452	177.129	195.775	5	3	7	932.260	531.388	1.370.422	0	0	1	6	4	9
198.886	188.942	208.830	6	4	8	1.193.316	755.767	1.670.642	1	0	1	8	5	11
208.119	197.713	218.525	6	4	8	1.248.714	790.852	1.748.200	1	0	1	8	5	11
197.240	187.378	207.102	7	4	10	1.380.681	749.513	2.071.022	1	0	1	9	5	13
201.712	191.627	211.798	8	5	11	1.613.697	958.133	2.329.776	1	0	1	10	6	15
206.184	195.875	216.493	9	6	12	1.855.658	1.175.250	2.597.921	1	1	1	11	7	16
207.912	197.517	218.308	10	6	14	2.079.122	1.185.099	3.056.309	1	1	1	12	7	18
209.640	199.158	220.122	11	7	15	2.306.042	1.394.107	3.301.833	1	1	2	14	8	19
211.368	200.800	221.937	12	8	16	2.536.418	1.606.398	3.550.985	1	1	2	15	9	20
213.096	202.441	223.751	13	8	18	2.770.250	1.619.531	4.027.518	1	1	2	16	9	23
214.824	204.083	225.565	14	8	18	3.007.538	1.632.664	4.060.177	1	1	2	17	9	23

Table D-7: Calculation of Annual Tool Steel Potential for Other Manufacturers

[348] Data from LMC Automotive, Uddeholm internal, accessed April 10th 2013
[349] Estimations according to a Discussion with Mr Pär Emanuelsson, Sales Director Uddeholms AB
[350] Estimations according to a Discussion with Mr Pär Emanuelsson, Sales Director Uddeholms AB
[351] Estimations according to the results of chapter 7 followed by a Discussion with Mr Nader Asnafi, Vice President – Research and Development, Uddeholms AB
[352] Estimations according to the results of chapter 7 followed by a Discussion with Mr Nader Asnafi, Vice President – Research and Development, Uddeholms AB
[353] Estimations according to the results of chapter 7 followed by a Discussion with Mr Nader Asnafi, Vice President – Research and Development, Uddeholms AB

Total line need to meet potential production [#]	Total line need to meet potential production [#] LOW	Total line need to meet potential production [#] HIGH	Total die potential of die sets [# sets]	Total tool steel potential [tons]	Total tool steel potential [tons] LOW	Total tool steel potential [tons] HIGH
89	89	89	230	1.310	1.310	1.310
108	106	110	264	1.508	1.477	1.538
130	116	145	311	1.772	1.582	1.973
148	133	164	346	1.973	1.768	2.190
160	144	176	382	2.175	1.958	2.403
178	149	208	415	2.366	1.989	2.767
195	165	226	445	2.536	2.151	2.945
211	180	243	471	2.687	2.297	3.100
218	176	262	500	2.850	2.303	3.433
235	192	281	528	3.012	2.457	3.602
253	208	300	557	3.174	2.613	3.770
269	211	330	580	3.306	2.595	4.064
284	225	346	601	3.426	2.718	4.182
288	230	350	613	3.496	2.790	4.248
290	220	364	621	3.541	2.693	4.446
291	211	351	629	3.586	2.599	4.330

Table D-8: Calculation of Total Line Need and Total Tool Steel Potential

Appendix E: Material Mix for C-Segment

Group	Model	Start of Production	Total Mass of Body in White	Low Strength Steels	High Strength Steels	Advanced High Strength Steels	Ultra High Strength Steels	Press Hardened Steels	Aluminium Extrusion Profiles	Others
Volvo[354]	S40	1995	n. sp.	63,6	36,4					
Ford[355]	Focus	2004	n. sp.	51,4	39,4	7,7		1,5		
Opel[356]	Astra	2004	n. sp.	49	41	8			2	
Volvo[357]	S40	2004	n. sp.	45,9	31,3	20,3		2,5		
Opel[358]	Astra	2009	n. sp.	34	43	17		4	2	
Ford[359]	Focus	2010	280,8	40,2	30,1	18,6	2,4	8,8		
Honda[360]	Civic	2011	273,9	41,6	43,1	4,5		6,2	4,6	
BMW[361]	1 Series	2011	267	20	58	16		3		3
Opel[362]	Ampera	2011	n. sp.	20,5	53,6	11,6	9,1	5,2		
Audi[363]	A3	2012	246,5	30,2	26,8	16,6		26,4		
Volkswagen[364]	Golf VII	2012	247	20	43	9		28		

[354] Mr Nader Asnafi, Vice President – Research and Development, Uddeholms AB
[355] Data from Conference "Aachener Karosserietage 2011", The new Ford Focus, p. 19
[356] Data from Conference "Strategies in Car Body Engineering 2012", Lower Body Structure at Opel, p. 46
[357] Mr Nader Asnafi, Vice President – Research and Development, Uddeholms AB
[358] Data from Conference "Materials in Car Body Engineering 2010", Structure material selection for the new Opel Astra, pp.41
[359] Data from Conference "Aachener Karosserietage 2011", The new Ford Focus, pp.14-18
[360] Data from Conference "Euro Car Body 2012", Car body benchmarking data summary Honda Civic, p.4
[361] Data from Conference "Euro Car Body 2012", Car body benchmarking data summary BMW 1 Series, p.4
[362] Data from Conference "Strategies in Car Body Engineering 2011", The new Opel Ampera, p. 38
[363] Data from Conference "Euro Car Body 2012", Car body benchmarking data summary Audi A3, p.4
[364] Data from Conference VDI-Konferenz Stahl im PKW 2012, Anforderungen an den Werkstoff Stahl zur Umsetzung von Leichtbauch in der Großserienfertigung von Volkswagen, p. 16

Appendix F: Member States of the European Union

The 27 Member States of the European Union:[365]

- Austria
- Belgium
- Bulgaria
- Cyprus
- Czech Republic
- Denmark
- Estonia
- Finland
- France
- Germany
- Greece
- Hungary
- Ireland
- Italy
- Latvia
- Lithuania
- Luxembourg
- Malta
- Netherlands
- Poland
- Portugal
- Romania
- Slovakia
- Slovenia
- Spain
- Sweden
- United Kingdom

[365] European Union, www.europa.eu/about-eu/countries/member-countries/index_en.htm, accessed 12th April 2013